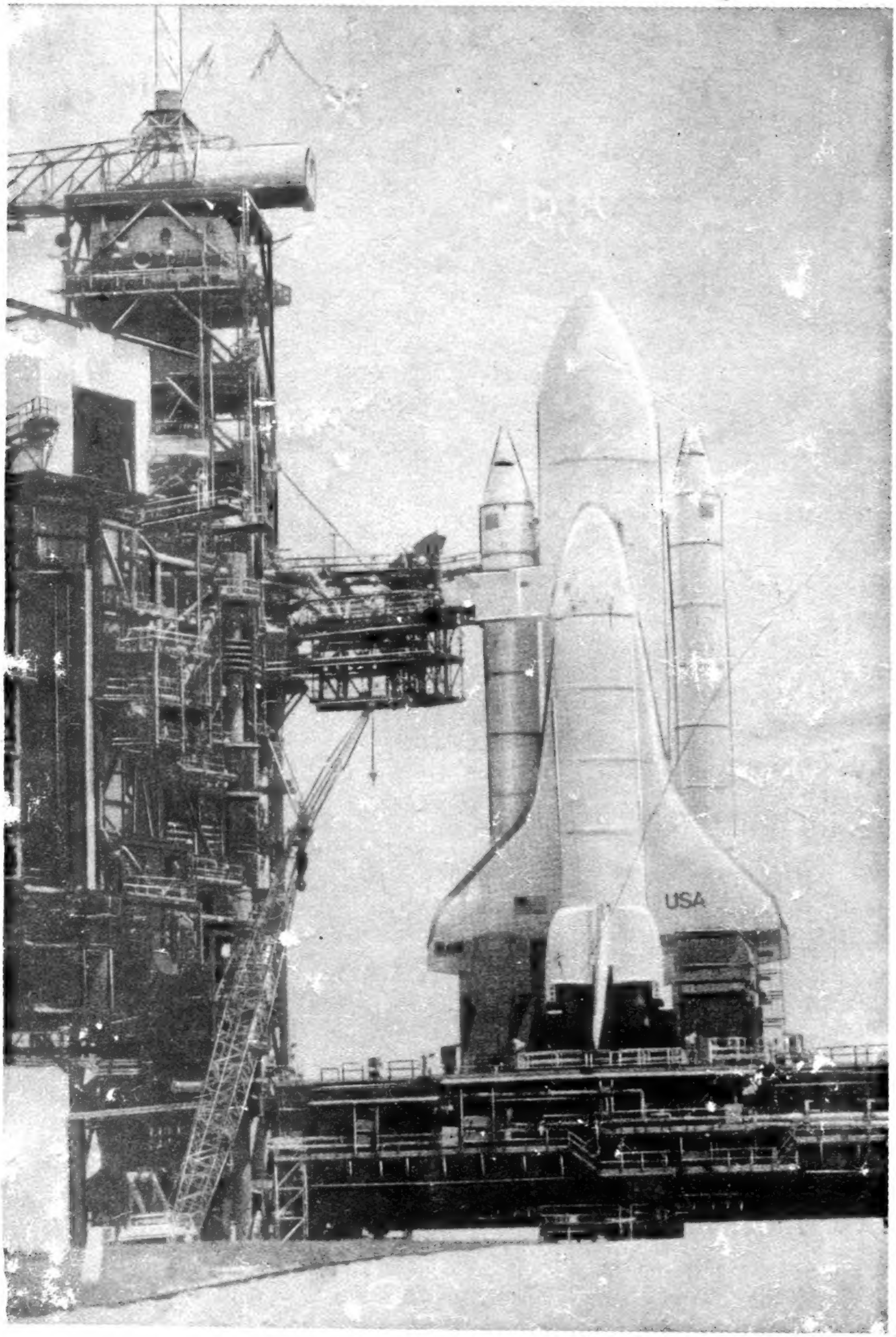
ISSN 0038-6340

SPACEFLIGHT

VOLUME 22 No. 1 JANUARY 1980

Published by The British Interplanetary Society



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COVER

ON THE PAD. Space Shuttle 'Enterprise' on Launch Complex 39A at the Kennedy Space Center, Florida. The 'facilities verification vehicle' was used to check pad and service tower clearances, and various servicing activities, ready for roll-out of the flight vehicle 'Columbia.' More pictures on pages 27-31.

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 NO. 1 JANUARY 1980 *Published 15 December 1979*

MILESTONES

September

11 *Novosti* announces that a ground experiment has been completed in readiness for the flight of the next Cosmos bio-satellite. Scientists were able to make "a complete assessment of research equipment and the state of animals and other biological subjects in conditions very close to those of actual space flight." During the forthcoming flight "it is proposed to conduct the first research into the development of mammal and bird embryos in weightless conditions. NASA, which is participating in the experiment, explained that a group of control animals identical to those going into space would be housed in an identical spacecraft on the ground, being subjected to the same vibratory and gravity forces of launch and re-entry as the orbiting animals. They will experience any changes which occur in the orbiting craft as those changes are transmitted to Earth. This synchronous control will help ensure that difference between control and flight animals can be attributed to the experience of weightlessness.

18 Seven-member delegation from People's Republic of China begins discussions in Washington and elsewhere with NASA officials on a memorandum of understanding for China's use of Landsat Earth resources satellites. International interest in satellite remote sensing is widespread and growing. Foreign-funded ground stations are now operating in Brazil, Italy, Canada (two facilities), Japan and Sweden. A ground station near Hyderabad, India, began test training with Landsat 2 last August. Argentina and Australia each have a Landsat ground station under construction. Stations are planned by Chile, Zaire, Upper Volta, Kenya, Romania, Thailand and New Zealand.

20 According to Indian Space Research Organisation (ISRO), India's first attempt to launch a four-stage, all-solid propellant satellite launcher SLV-3 on 10 August failed because of a guidance malfunction of the second stage. It is planned to launch a second SLV-3 in the last quarter of 1979.

20 NASA launches third and last High Energy Astronomy Observatory (HEOA 3) from Cape Canaveral by Atlas-Centaur into 309 mile (497 km) orbit. Objective of 6,500 lb (2,948 kg) observatory is to provide more information on gamma and cosmic rays.

[Continued on page 45

NEW PRINTING ARRANGEMENTS

In view of the pressure of work on our small Headquarters staff and other considerations arising from the introduction of 'new technology' in the printing industry, it has been necessary to transfer the setting of material for *Spaceflight* and *JBIS* to our printers, Unwin Brothers Ltd., in Woking, Surrey.

For the past six years – at a time of high inflation and severe financial restraint due to the priority given to the Society's Development Programme, involving the acquisition and re-construction of our Headquarters Building – the task of setting both publications has fallen almost exclusively upon our very willing Assistant Secretary, Miss Shirley Jones. However, it has always been recognised that this situation could not last indefinitely. The advent of computer setting, and the obsolescence of our existing manual equipment (IBM Composer) at HQ – and the difficulty of ensuring maintenance of this and the near-impossibility of obtaining staff willing to operate oldequipment – have compelled us to make new arrangements, although we have to face the fact that this will involve the Society in much greater expense.

Our printers have promised to make the changeover as smooth as possible but it is anticipated that some delay may occur due to production problems coming at a time of the extended Christmas Holiday. We therefore ask members to bear with us if the February issue is a little late in reaching them. Ed.

NAVSTAR - A COMPLETE GLOBAL NAVIGATION SYSTEM

By Geoff Richards

Introduction

In five years' time nearly all terrestrial navigation needs could be met by a single system of orbiting satellites that could replace the present mix of radio, inertial and satellite navigation aids, and in addition could provide a navigation service for space vehicles in cislunar orbits. The system that is currently being developed to provide this service is the US joint services Global Positioning System, also known as NavStar (for Navigation System using Time and Ranging). Several development satellites have already been launched and full operational capability should be achieved by the middle of the 1980s. User equipment is being developed for practically every type of military vehicle, from jeeps to cruise missiles, from ships to supersonic aircraft, and there is even a receiver under development that is light enough to be carried by an individual infantryman.

While the basic application of NavStar is military (both for the US and for the rest of the NATO alliance), user equipment that does not have the capability to exploit the full accuracy of the system will be commercially available. This equipment will nevertheless have sufficient accuracy for most civilian applications. Typical errors will be around ten metres for military equipment and a hundred metres for civilian equipment. Initially, civilian receivers are expected to cost a minimum of twenty-thousand dollars. This means that conventional radio-navigation aids will be considerably cheaper where they are available, so the initial civilian market is likely to be for transoceanic applications. For instance, a large ship could recoup the cost of a NavStar receiver in the fuel savings that accurate navigation would bring on a single Atlantic crossing. In the long run, however, once the market builds up, receiver prices are expected to come down to a few thousand dollars, within the reach of light-aircraft operators and private yachtsmen.

The Method

The NavStar navigation technique is simpler in concept but more difficult to develop than the radio-Doppler method used in the Transit satellite system (*Spaceflight*, February 1979). The NavStar method is based on time ranging. In other words, a user calculates his distance from a satellite from a measurement of the time that the satellite's radio transmissions, travelling at the speed of light, take to cover the distance. As with Transit, the satellite transmits data that provide users with the necessary information on the position of the satellite at the moment the signals are transmitted. The user needs to know his distance from three separate satellites in order to obtain a complete three-dimensional fix. Once he knows his position he can also obtain his velocity, again in three dimensions, from the Doppler shift in the received signals.

Since the speed of light is so great, the use of the time ranging method is only possible if both the transmitter and the receiver have a method of measuring time to extremely high accuracy. The NavStar satellites carry atomic clocks to provide such accuracy, but it would be unreasonably costly to provide each user with such equipment. Instead, sufficient satellites will be launched to ensure that four rather than three will be in view from any point on the Earth's surface at any time. In these circumstances the user can calculate an extra dimensional fix, that of time, from his observations of the four satellites.

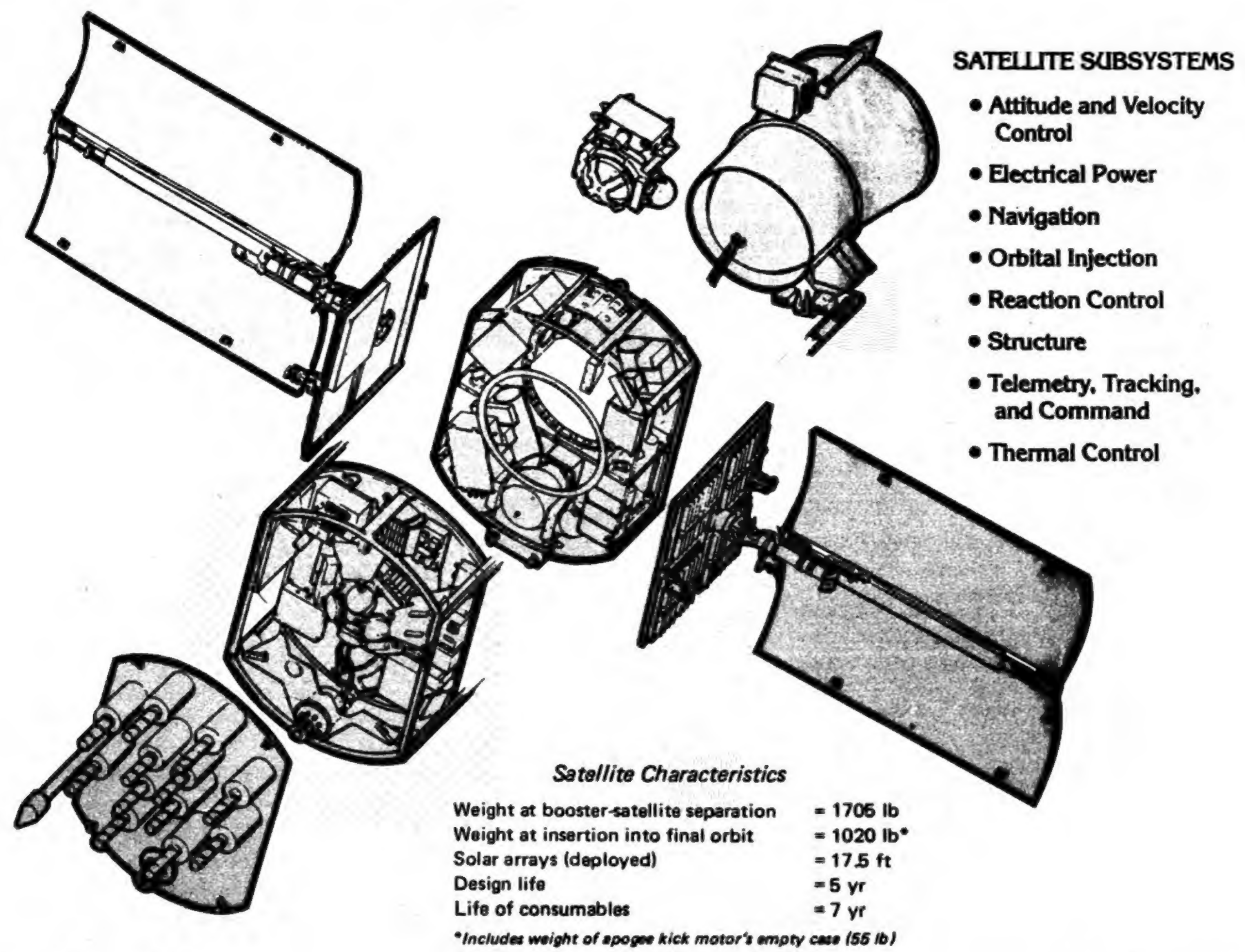
To achieve the required four-satellite coverage the operational NavStar system will consist of twenty-four satellites, eight in each of three orbital planes inclined at 63° to the equator and equally spaced in longitude. The orbits will be circular at an altitude of 20,200 km, so that the orbital period of each satellite will be twelve hours. Each satellite will be able to manoeuvre to reach the correct position in the constellation. A ground control segment, as with Transit, will form part of the system and will track the satellites, calculate predicted satellite positions, and generally control the information that the satellites transmit to the users. The headquarters of the NavStar ground segment is currently at Vendenberg Air Force Base in California, together with the uplink transmitter and one of the tracking stations. Three other tracking stations are in operation. These are located in Hawaii, Alaska and Guam and are unmanned, being remotely controlled from Vandenberg AFB. Each satellite will have orbital data and clock corrections transmitted to it at least once a day, so the workload involved in controlling the full 24-satellite operational system will be considerable. A new headquarters will be constructed at Fortuna Air Force Station in North Dakota to perform this task.

The Navigation Signal

The measurement of the tranit time of the radio transmissions from the satellite to the user is made possible by modulating the transmissions with a pseudo-random noise (PRN) signal. This is a signal that appears random on the surface but is in fact generated by a predetermined mathematical formula. The user's receiving equipment generates the same PRN sequence and then performs a mathematical operation called cross-correlation which in effect varies the time at which the user's sequence starts until the two sequences are identical. The time offset of the user's PRN sequence is then equal to the transit time of the satellite's signal. NavStar in fact uses a double system in which two PRN signals are transmitted simultaneously. The first signal, the C/A (coarse/acquisition) code, has a bit rate of 1.023 MHz and the sequence repeats at millisecond intervals. This is the only code that will be available to civilian users, so C/A also stands for clear access. The millisecond repetition rate of this code produces an ambiguity of a light-millisecond (about 300 km) in distance unless the user's clock has better than millisecond accuracy, but in practice this should not be a problem. The C/A code is transmitted on a frequency of 1575.42 MHz, an exact multiple of the bit rate.

The data transmissions from the satellite provide the user with the time, the precise orbital position of the satellite, and approximate positions of all the other satellites in the system. Military users can also obtain the required information to lock into the second PRN sequence, the P (for precision) code. This has a bit rate equal to the oscillater frequency of 10.23 MHz and ten times that of the C/A code, thus giving ten times the accuracy, and repeats once a week rather than every millisecond. This long sequence is designed to prevent any non-authorised user from breaking the code and using the full accuracy of the system. The dual-frequency method of Transit has been adopted so that users can measure and compensate for ionospheric refraction effects. For this reason one of the PRN codes, normally the P code, is transmitted on 1227.60 MHz in addition to 1575.42 MHz. Neutral atmospheric refraction is approximated in the calculation of position, but since this depends on atmospheric conditions that are never completely known there is inevitably some error in the correction. When using the P code and dual-frequency this effect constitutes the largest single source of error in the calculated position of the user.

A slight draw-back to the use of PRN codes is the time it takes for the receiving equipment to acquire signals from



Navstar: Exploded view

Rockwell International

four satellites and then perform the cross-correlation operations. Even with the best equipment it will take tens of seconds to obtain an initial fix, while a simpler receiver could take several minutes. This sort of delay is only marginally acceptable for aviation use and military aviation receivers will include an inertial platform to fill in the gaps. Once a multi-channel receiver is locked into the satellites' signals it will provide updated position information every few seconds, so the delay is only significant if contact is lost for some reason.

The Origin of NavStar

Around 1964 both the US Air Force and the US Navy started investigating the possibility of a time-ranging satellite navigation system. The USAF investigations grew into Program 621B which envisaged the use of three satellite constellations at 120° intervals over the equator. Each constellation would have consisted of four satellites, one in exact geostationary Clarke orbit and the other three in slightly elliptic inclined 24-hour orbits. From the Earth each constellation would have formed a letter Y that rotated once a day. The main disadvantage of this configuration is the lack of coverage of the polar regions. No information is available as to whether the USAF launched any test satellites, but they did carry out an extensive programme of tests on the ground. These involved the "inverted range" concept, in which the navigation transmitters were on the ground and the user aircraft flew over them rather than under a satellite constellation. These initial tests were conducted at Holloman AFB, New Mexico.

The Navy, in contrast, favoured a system of satellites in high-altitude circular orbits, similar to the eventual NavStar configuration. The Navy adopted the name Timation (a contraction of time navigation) for their programme and started launching test satellites in 1967. In 1973 the Department of Defense insisted that the two services merge their efforts into a joint programme and the Global Positioning System was the result. Side-tone ranging, which was tested on several of the Navy satellites, was a possible alternative to PRN for the navigation signal, but in spite of protests from potential civilian users this cheaper method was not selected as PRN offered much greater security against non-authorised use.

The USAF was given overall management responsibility for NavStar, while the Navy is responsible for the continuing development of the satellite clocks in an extension of the Timation work. The US Army also joined the programme, providing a new inverted range at their proving ground at Yuma, Arizona. All three services, plus the US Marines and several other US government organisations, are involved in developing user equipment for their respective needs.

Some twenty years will have elapsed between the start of work on time ranging and the full operational deployment of NavStar. The most important factor in pacing this development has been the frequency stability of the available oscillators for satellite use. While the crystal oscillators used by the Transit system are highly accurate by everyday standards, they fall far short of the requirements of the time

ranging method for comparable overall navigation accuracy. NavStar therefore had to wait for the development of better clocks for satellite use, with a performance several hundred times better than Transit-type oscillators. This means a frequency stability of around one part in ten million million, or one second in 300,000 years. With this sort of performance the clock-induced navigation errors are kept to a metre or so if the clock is corrected every day. An interesting side-effect of such high accuracy is the fact that the satellite oscillator has to be slightly offset from the nominal frequency to allow for the gravitational effect on time between the ground and the satellite's orbital altitude. This is possibly the first engineering application of the general theory of relativity.

The Test Satellites

The Naval Research Laboratory in Washington, DC has built several satellites to test oscillators and other systems for the Timation and NavStar programmes. The first of these, Timation 1, was launched by the USAF from Vandenberg AFB in May 1967, hitching a lift into space on the aft rack of an Agena stage that carried a collection of small military payloads. The satellite was a 0.81 m. long box in shape, with a mass of 39 kg. Solar cells on the surface of the box provided 6 watts of electrical power and the payload consisted of a quartz crystal oscillator and a transmitter broadcasting at 400 MHz. The crystal oscillator was considerably more stable than the Transit type, but it was susceptable to radiation-induced frequency changes. The lack of dual-frequency ionospheric correction capability was an additional factor in limiting the navigational accuracy to a few hundred metres. The navigation technique with Timation [1] involved repeatedly ranging the single moving satellite rather than simultaneously ranging several satellites.

An improved crystal oscillator was flown on Timation 2 two years later. This oscillator was about three times more stable and was shielded against radiation. A dual-frequency transmitter using the standard 150 and 400 MHz navigation frequencies was carried and the satellite was somewhat larger, more powerful (19 W) and heavier (57 kg.) than its predecessor. Launch was again as part of an Agena multiple payload. Navigation accuracy was improved to around 100 m, but radiation was still a problem as the shielding was mainly effective against electrons and it was not realised until 1972 that protons were the cause of the trouble. The oscillators of Timation 2 and its successors were each in their time the most stable available in orbit and therefore, in addition to navigation tests, they were used for synchronising time standards between national observatories in different continents.

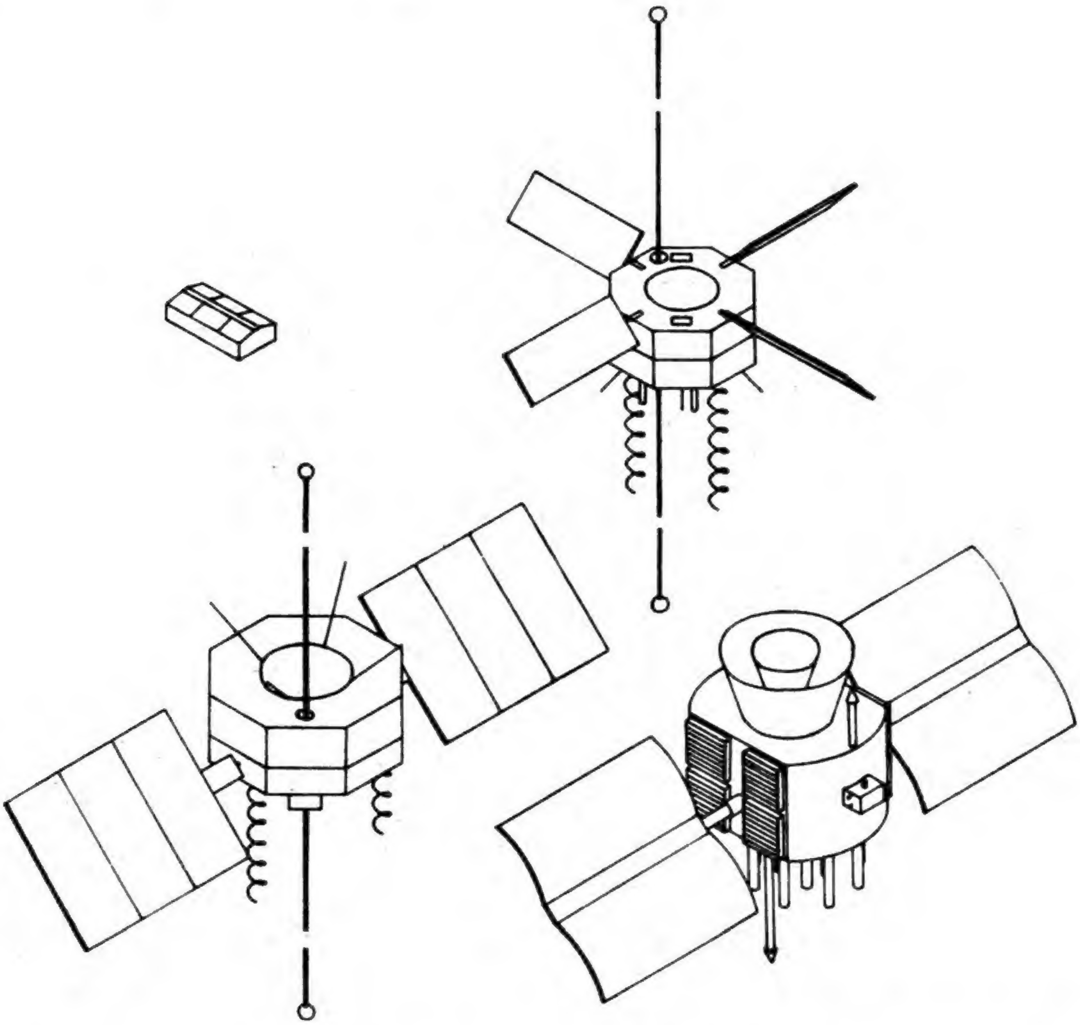
Timation 3 was under construction at the time that the Navy programme was merged into NavStar. The satellite was adopted by the new programme as the first Navigation Technology Satellite (NTS 1). At about the same time the first lightweight atomic clock, a rubidium vapour device, was put on the market by Efratom, a West German company. In the few months before launch two these clocks were flight-rated and integrated into the payload in addition to the usual quartz oscillator. The satellite was a toroidal octagonal prism with a mass of 295 kg. and a diameter of 1.22 m. Four solar-cell panels provided Earth-pointing stabilisation. Transmission frequencies were 335 MHz and (for the first time) the operational 1575 MHZ. In addition to the basic navigation payload the satellite carried optical reflectors for laser tracking, experimental solar cells for space testing, and radiation-monitoring instruments.

Time ranging, unlike the Transit method, does not need rapidly-moving satellites, so slower high-altitude orbits can be used. Such orbits provide the benefits of a smaller number of satellites required to provide global coverage, the lack of atmospheric drag to perturb the orbits, and less need for radiation protection for the satellite systems. Since, for the first time in the programme, a dedicated launch vehicle was available for NTS 1, this satellite was the first to use a high orbit. The launch vehicle, an Atlas F with a Payload Transfer System upper stage, placed Nts 1 into the orbit originally envisaged for the Timating system, with a period of 8 hours rather than the 12-hour orbit of the operational Navstar system. After launch (in July 1974), the satellite developed a slow tumble in orbit due to a failure in the attitude damping device. However, the rubidium vapour clocks demonstrated satisfactory operation and as a result of this they were chosen for the first prototypes of the operational satellites.

The most recent of the test satellites has been NTS 2. The main objective of this satellite was to flight-test a caesium-beam type of atomic clock, several times more accurate than the rubidium type. Additional tests included further laser reflectors, solar cells and radiation instruments, and the first space test of a nickel-hydrogen battery. The satellite was generally similar to NTS 1, though larger, with a mass of 440 kg. and a diameter of 1.65 m. Two large Sun-pointing solar panels replaced the four smaller fixed panels of the earlier satellite and provided 400 W. The full PRN navigational payload was carried for the first time and the satellite was placed in a 12-hour orbit so that it could form part of the initial constellation with the first few prototype satellites. This orbit was achieved with the use of the twin-stage SVS (Stage Vehicle System) on an Atlas F booster, rather than the single-stage PTS used for NTS 1. NTS 2 was launched in June 1977 and, like its predecessor, showed that its two clocks were suitable for space use. Caesium clocks are therefore currently being phased into the programme. Unfortunately the navigation system of NTS 2 failed in February 1978 so the satellite did not in the event contribute to the initial constellation, though prior to the failure

Table of Timation and NavStar Launches

Programme	Launch Data Date	Vehicle	Site	Perigee (km)	Apogee (km)	Period (min)	Incl. (deg)
Timation 1	31 May 1967	Thor-Agena D	WTR	915	926	103.39	69.91
Timation 2	30 Sep 1969	Thorad-Agena D	WTR	906	940	103.48	70.02
NTS 1	14 Jul 1974	Atlas F-PTS	WTR	13445	13767	468.40	125.08
NTS 2	23 Jun 1977	Atlas F-SVS	WTR	19545	20187	705.18	63.28
NDS 1	22 Feb 1978	Atlas F-SVS	WTR	20095	20308	718.67	63.27
NDS 2	13 May 1978	Atlas F-SVS	WTR	19958	20094	711.65	63.13
NDS 3	7 Oct 1978	Atlas F-SVS	WTR	20283	20310	722.60	62.81
NDS 4	11 Dec 1978	Atlas F-SVS	WTR	20266	20315	722.39	63.27



Timation and NavStar satellites shown to scale. *Upper left:* Timation 1, *upper right:* NTS 1, *lower left:* NTS 2, *lower right:* NDS.

successful navigation tests were conducted in conjunction with the Yuma inverted range.

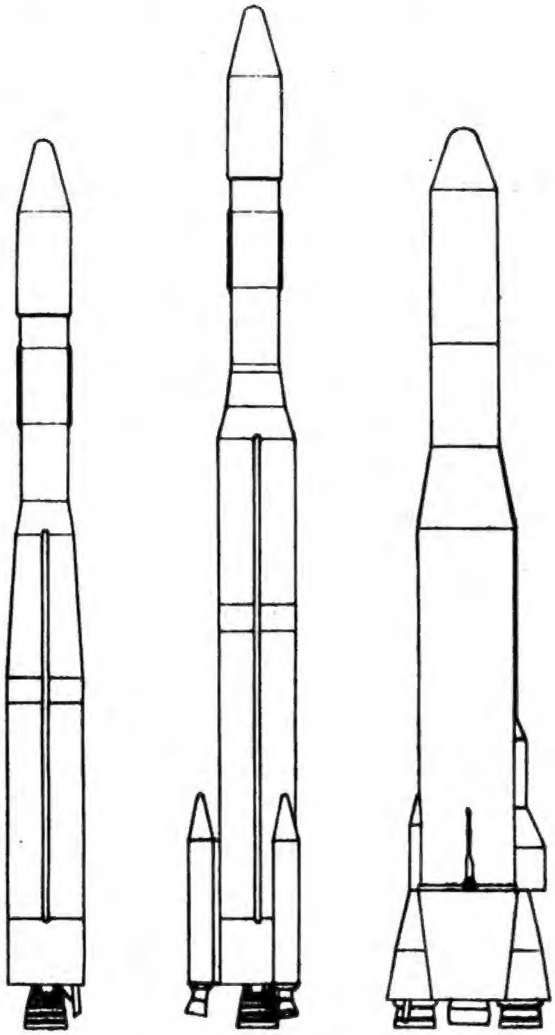
A third NTS is currently under development. This is scheduled to be launched in 1981 or 1982 and will test a flight-rated version of the tultimate in current time-measuring technology, a hydrogen maser frequency standard. This promises a ten-fold improvement in accuracy over a caesium clock and should enable the NavStar system to operate for a few weeks without ground correction.

The Operational Programme

The prototype operational satellites are known as Navigation Development Satellites (NDS). They are manufactured by Rockwell International and, like NTS 2, are launched by Atlas F-SVS vehicles. Each satellite is a cylinder 1.5 m. in diameter with a mass of about 455 kg. Two solar panels span 5.3 m. and provide an initial 580 W. The clock system uses three rubidium vapour oscillators. The satellite is stabilised so that one end of the cylinder faces the Earth, while the solar panels are driven to track the Sun. Three nickel-cadmium batteries provide power during eclipse periods. The main transmitting antenna is an array of twelve helical elements on the base-plate, and omnidirectional command and telemetry antennae are mounted on both end-plates. Louvred panels on the sides form part of an active thermal control system for the payload. The nozzle of the apogee motor protrudes from the top of the satellite and two pods on the sides contain hydrazine jets for attitude and orbit control. An infra-red Earth-sensor and panel-mounted Sun-sensors provide inputs to an attitude control system that uses four reaction wheels in addition to the gas jets.

Launch involves a complex series of operations. Following Atlas burn-out the satellite/SVS combination is spin-stabilised. After the burns of the two SVS stages the satellite separates from the SVS and then performs a 180° precession manoeuvre in the resulting elliptical transfer orbit in order to attain the correct orientation for the apogee motor burn. Typically, this occurs after two or three days in the transfer orbit. Unlike NTS, the apogee motor is not jettisoned after burn-out. Following the apogee burn another precession manoeuvre of 90° points the base of the satellite towards the Earth. The satellite is then de-spun and the orbit adjusted as required by firings of the gas jets. Finally the solar panels are deployed and pointed towards the sun.

The initial constellation consists of four satellites in two orbital planes, grouped so that all four are visible together for four hours a day over the North American continent. To date (mid 1979) NDS 1 and 4 have been launched into one plane and NDS 2 and 3 into the other. While the constellation was building up the system was tested by using the available satellites in conjunction with ground-based transmitters at



Launch Vehicles used to date in the Timation and NavStar programmes. *Left to right:* Thor-Agena D, Thorad-Agena D, and Atlas F. The PTS or SVS upper stages of the Atlas F are completely enclosed in the payload shroud. Plans for future NavStar launches involve new upper stages for the Atlas F and use of the Shuttle with various upper stages.

the Yuma range. The deployment of the initial constellation has not yet been entirely problem-free. The clock electronics had to be modified after one unit on NDS 1 failed after only six weeks in orbit and there have been launch delays caused by various problems with both the satellites and the Atlas F. However, the initial experience with the system has been very encouraging and the navigation accuracy has been well up to specification. NDS 4 carried a caesium clock for engineering evaluation and it is hoped to use these devices operationally from NDS 7 onwards.

Following completion of the initial feasibility demonstration phase of the programme the four-satellite constellation will be expanded to six and maintained by replacement launches as required while the user equipment is developed to operational standard. A new upper stage for the Atlas F is under consideration for later launches as future satellites are expected to be heavier than the prototype batch of eight. This is due not only to modifications to improve the basic navigation payload, but also to the planned addition to each satellite of a communications transponder and sensors to detect clandestine nuclear weapon tests. The single-channel communications transponders would form part of the USAF AFSatCom system.

Deployment of the full 24-satellite operational constellation is expected to begin in 1984, with satellites launched in multiple packs by the Shuttle/IUS combination. Once the supply of Atlas F vehicles is exhausted, individual replacement launchers would also be Shuttle-boosted, though a smaller spin-stabilised stage would be used instead of the IUS for transfer orbit injection. With design life for the operational satellites increased to 7.8 years, compared with 4.5 years for the prototypes, three or four replacement launches a year will be needed to keep the system up to strength. There is every reason to believe that NavStar will prove as long-lived as Transit, so such launches should continue into the twenty-first century.

KNOW YOUR COUNCIL

GORDON J.N. SMITH graduated from Imperial College, London, in 1956 with degrees in mathematics and aeronautics. He works at British Aircraft Corporation, Bristol on aerodynamics, performance and control of guided weapons, including Bloodhound and various future projects. He joined de Havilland Propellers–later to become Hawker Siddeley Dynamics–in 1961 at their Charterhouse Square, London offices. He was mainly involved in the design studies for development of the UK first stage of the European satellite launch vehicle.

Mr Smith joined the BIS in 1961. In 1964 he was a member of the project team who bid and won the contract for developing the first European satellite ESRO 2. He was responsible for the design and development of the magnetic attitude control system and analysis of the orbital dynamics. He gave a paper on the control system at the 1966 IAF Congress in Madrid.

In 1968 he was appointed Assistant Chief Dynamics Engineer and moved to the HSD Stevenage site. He was closely involved in the aerodynamics, structural loadings and control aspects of the three-stage ELDO vehicle involving close links with such companies as MATRA, ERNO, AERITALIA and General Dynamics.

In 1970 Mr Smith spent four months at Messerschmitt-Bolkow-Blohm, Munich, as Chairman of the Guidance and Control Panel of the US/European Board set up to review the German third stage following in-flight failures.

In 1973 he was appointed Design Manager of the European Space Tug Studies under ELDO contract, with HSD heading a consortium of 10 European Companies. He presented a paper on the design at the 1972 IAF Congress in Vienna.

Mr Smith joined the newly formed HSD Systems Engineering Department in 1975, and became closely involved in the effort to market regional satellite communications systems derived from the OTS and ECS programmes.

In 1976 he was appointed Chairman of the UK Ariane Review Panel. In 1977 he was seconded as Project Manager heading an HSD team to assist INTA, Madrid in the design and development of a national sounding rocket. Also, in 1977 he was awarded the CDip AF of the Association of Certified Accountants after a year's part-time study.

Mr Smith is a Chartered Engineer and a member of the RAeS and AIAA. He became a member of the BIS Council in 1977 and was appointed co-Editor of the *JBIS* 'Space and Education' series in 1978.

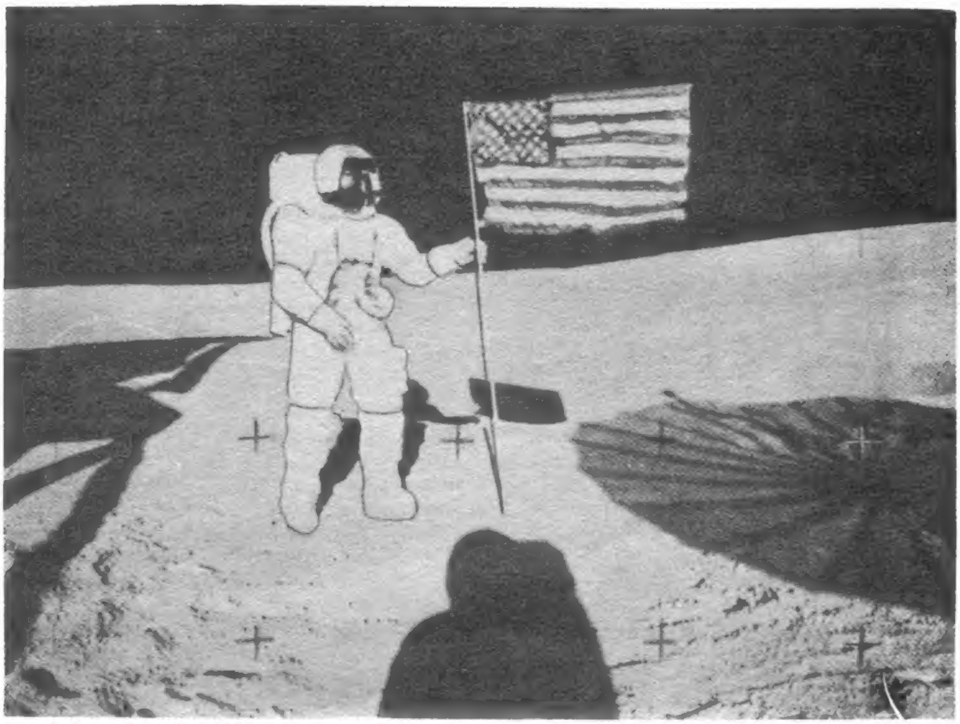
Following appointment as Project Manager on Military Space Systems, Mr Smith transferred to British Aerospace Dynamics Group, Bristol in November, 1978.

A photograph of Gordon appears on page 230 of Spaceflight, May 1979.

RETURN TO APOLLO

By Andrew Wilson and David J. Shayler

A retrospective look at the men of Apollo



WHERE NO WINDS BLOW. Alan Shepard, commander of the Apollo 14 mission, poses beside the Stars and Stripes held erect by a metal rod. The picture was made by fellow astronaut Ed Mitchell (shadow) at *Fra Mauro* on 5 February 1971.

NASA

Introduction

A great deal of attention has been given in the pages of *Spaceflight* to the composition of Soviet space crews. U.S. crewing policy, on the other hand, has largely been ignored by writers because it has been assumed to be general knowledge to the average reader. This article attempts to fill the gap by looking at the history of the Apollo programme and how its twists and turns influenced the selection of astronauts for missions. For example, what would the later Apollo crews have been like if the Apollo 1 fire had not occurred? This question is considered in some depth in a later section and part of the answer is that Edward White probably would have commanded one of the later flights to the Moon.

The reasons for particular selections or omissions of astronauts were not always clear to the public and since this article is based on published information some of the comments and deductions may later be shown to be in error by the publication of an astronauts' autobiography which provides some 'inside' information. It was, in fact, the autobiography of astronaut Michael Collins [1] giving a glimpse behind the scenes of Gemini and Apollo which first suggested the article to the authors.

A second article will deal in a similar way with projects Mercury and Gemini.

Astronaut Selection

In the early days of American manned space flight it appeared that a large number of astronauts would be needed to reach the Moon and continue with later flights and programmes. Consequently, a total of seven astronaut groups was selected during the 1960s to meet envisaged targets. Table 1 lists the groups and their astronauts to help the reader in later paragraphs, since, in general, an astronaut from an early group stood a good chance of making his first flight before an astronaut from a later group. This helps us to establish a simple form of seniority among the men of all groups, illustrated by the fact that none of the groups 6 and 7 astronauts have yet flown in space. Group 7 is different from its predecessors because it was made up of men assigned from the cancelled US Air Force Manned Orbiting Laboratory in August, 1969. Groups 4 and 6 both consist entirely of scientist astronauts. In general, group 1 members can be thought of as the Mercury astronauts, group 2 as the Gemini astronauts and groups 2, 3 and 5 as the Apollo astronauts but it must be remembered there are no clearly defined rules.

Apollo Missions

In planning the sequence of Apollo flights, NASA evolved a system whereby a particular type of mission was assigned a letter code [2]. The initial batch was of mission types A to G, beginning with unmanned Command and Service Module (CSM) flights and progressing through logical steps to the initial lunar landing:

'A' . . designed to man-rate the CSM and launch vehicles before the first crew went into space.

Five were flown:	AS-201 with February, 1966	CSM-009 in
	AS-202 August, 1966	CSM-011
	AS-203 July, 1966.	–
	Apollo 4 November, 1967	CM-017
	Apollo 6 April, 1968	CM-020

Table 1: NASA Astronaut groups and their members (April 1959–August 1969)

Group	*No. Selected*	*Date*	*Names*
1	7	Apr. 9, 1959	Carpenter, M.S.; Cooper, L.G.; Glenn, J.H.; Grissom, V.I.; Schirra, W.M.; Shepard, A.B.; Slayton, D.K.;
2	9	Sept. 17, 1962	Armstrong, N.A.; Borman, F.; Conrad, C., Lovell, J.A.; McDivitt, J.A.; See, E.M.; Stafford, T.P.; White E.H.; Young, J.W.
3	14	Oct. 18, 1963	Aldrin, E.E.; Anders, W.; Bassett, C.A.; Bean, A.L.; Cernan, E.A.; Chaffee, R.B.; Collins, M.; Cunningham, R.W.; Eisele, D.F.; Freeman, T.C.; Gordon, R.F.; Schweickart, R.L.; Scott, D.R.; Willams, C.C.
4	6	Jun. 28, 1965	Garriott, O.K.; Gibson, E.G.; Graveline, D.E.; Kerwin, J.P.; Michel, F.C.; Schmitt, H.H.
5	19	Apr. 4, 1966	Brand, V.D.; Bull, J.S.; Carr, G.P.; Duke, C.M.; Engle, J.E.; Evans, R.E.; Givens, E.G.; Haise, F.W.; Irwin, J.B.; Lind, D.L.; Lousma, J.R.; Mattingly, T.K.; McCandless, B.; Mitchell, E.D.; Pogue, W.R.; Roosa, S.A.; Swigert, J.L.; Weitz, R.J.; Worden, A.M.
6	11	Aug. 4, 1967	Allen, J.P.; Chapman, P.K.; England, A.W.; Henize, K.G.; Holmquest, D.L.; Lenoir, W.B.; Llewellyn, J.A.; Musgrave, F.S.; O'Leary, B.T.; Parker, R.A.R.; Thornton, W.E.
7	7	Aug. 14, 1969	Bobko, K.J.; Crippen, R.L.; Fullerton, C.G.; Hartsfield, H.W.; Overmyer, R.F.; Peterson, D.H.; Truly, R.H.

ONE SMALL STEP.... Astronaut Neil A. Armstrong coming down the ladder of Lunar Module 'Eagle' on the Sea of Tranquillity just prior to becoming the first human being to set foot upon the Moon.
NASA

'B' . . demonstrated the unmanned Lunar Module (LM) in the successful flight of Apollo 5 in January, 1968.

'C' . . the first manned flights of the CSM were to be 'C' missions. Apollo 7 in October, 1968 fitted this description. Apollo 8 was originally to have been an 'E' mission but when it was pulled forward in the schedule (discussed later) it became a lunar orbiting CSM flight and was designated as 'C-prime'.

'D' . . was designed to test out the LM for the first time with men aboard. Eventually undertaken by Apollo 9.

'E' . . after the Borman crew was shifted forward to 'C-prime' and Apollo 9 demonstrated the reliability of the LM, an 'E' flight was considered unnecessary. 'E' had been intended to fly the CSM LM combination to large-apogee distances.

'F' . . this was to be the complete lunar landing minus the actual landing, ie, Apollo 10.

'G' . . the initial lunar landing, achieved by Apollo 11.

Later on, the 'H' code was added and the final designation, 'J', was announced in 1970. They were essentially more sophisticated 'G' missions—extended stays on the Moon, Lunar Roving Vehicles carried and a large array of experiments. The CSM flown in the joint US-USSR Apollo Soyuz Test Project (ASTP) was of the 'H' type. Table 2 lists the mission type and launch date of each Apollo mission, together with their CM and LM serial numbers.

The scheduling of manned Apollo missions was being considered by NASA long before the first Gemini spacecraft had flown in 1964. By 1963 the first four manned flights were scheduled to be launched by the Saturn I booster but on 30 October, 1963 [3] all four were cancelled as a result of recommendations to change from the Saturn I to the Saturn IB for this type of mission. The Saturn I was used as the assumed launch vehicle for type 'A' flights when Requests For Proposals were issued to the companies bidding for Apollo in July, 1961. (David Baker has gone into this relationship between the Saturn booster and the development of Apollo in considerable depth [4]).

By December, 1963 NASA gave the initial launch dates for manned Apollos as:

1. Saturn IB, either SA-203 in third quarter 1966
   or SA-207 in third quarter 1967
2. Saturn 5, either SA-503 in third quarter 1967
   or SA-507 in second quarter 1968

It is apparent from the date of the schedule that group 2 and 3 astronauts would have been likely to fly these missions under the command of group 1 men. Officially, however, NASA said nothing on crew compositions. On 28 April, 1965 it was decided [5] that announcement of any Apollo crews should be delayed as long as possible without jeopardising training schedules. The reasoning was quite simple: men were undergoing general Apollo training so

Table 2: Apollo flights

Flight	Date	Type	CM	LM
AS-201	26 Feb 66	A	009	–
AS-202	25 Aug 66	A	011	–
AS-203	5 Jly 66	A	–	–
Apollo 4	9 Nov 67	A	017	LTA-10
Apollo 5	22 Jan 68	B	–	1
Apollo 6	4 Apr 68	A	020	LTA-2
Apollo 7	11 Oct 68	C	101	–
Apollo 8	21 Dec 68	C	103	LTA-B
Apollo 9	3 Mar 69	D	104	3
Apollo 10	18 May 69	F	106	4
Apollo 11	16 Jly 69	G	107	5
Apollo 12	14 Nov 69	H	108	6
Apollo 13	11 Apr 70	H	109	7
Apollo 14	31 Jan 71	H	110	8
Apollo 15	26 Jly 71	J	112	10
Apollo 16	16 Apr 72	J	113	11
Apollo 17	6 Dec 72	J	114	12

there was no need even to make tentative selections.

The question of which CSMs would be the first to fly men around the Earth was settled in a memo of 17 February, 1965 [5] which required CSMs 012 and 014, both Block I spacecraft, to be delivered to Kennedy Space Centre in manned configurations. Manned Spacecraft Centre (MSC) Deputy Director George Low had outlined Apollo's schedule on 7 January, 1965 [5] as:

1. First unmanned Saturn IB flight in 1966;
2. First manned Saturn IB flights in 1966;
3. First unmanned Saturn 5 flight in 1967;
4. Other manned Earth orbital flights in 1968.

CSMs 012 and 014, which we may label as Apollos 1 and 2, were scheduled for launch by SA-204 and SA-205, respectively, following three unmanned Saturn IB flights.

During 1965, Gemini was in full swing and required the attention of group 1, 2 and 3 astronauts but in December a significant change took place: following the highly successful Gemini 7 14-day mission, astronauts Grissom, McDivitt, White, Schirra and Borman left Gemini and began to concentrate on Apollo. Clearly, these men were due to fly the first Apollos in senior positions. Other crew positions would not require such extensive knowledge of the systems so the other Gemini astronauts could be left out of Apollo training for a while. Group 4 and, later, group 5 astronauts went straight into Apollo training.

Table 3 reviews the assignments for the Gemini series.

First Crew Assignments

By virtue of seniority, we would have expected Grissom to have been given the first flight, with Schirra getting the second. On 21 March, 1966 the first two crews were announced for the flight of Apollo 1/CSM 012 as:

Prime	Grissom	White	Chaffee
Backup	McDivitt	Scott	Schweickart

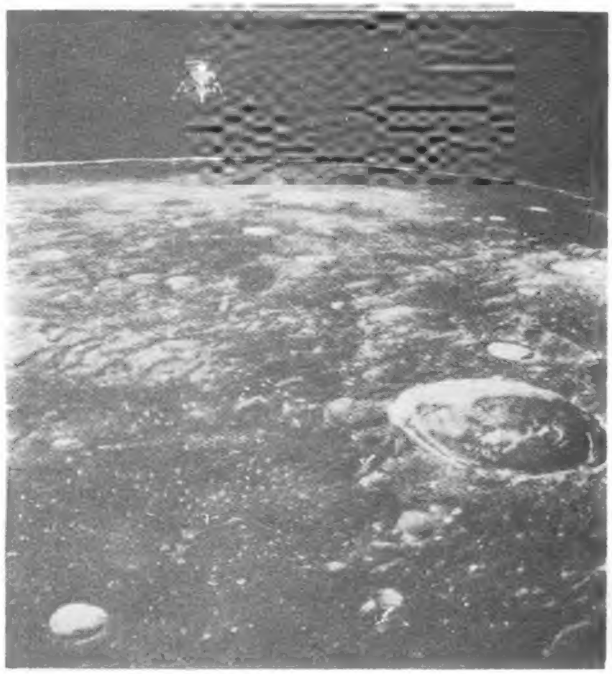
The commander and senior pilot positions were filled by experienced Mercury and Gemini astronauts, with 'rookies' –unflown astronauts–taking the less important pilot positions (in later missions these became the Lunar Module Pilots but Block I spacecraft were designed to fly without LMs).

Since Schirra had been left out of the crews in March it was obvious a further crew announcement would be made

Table 3 Astronaut assignments in the Gemini series.

Gemini	Commander	Pilot
3	Grissom (1) Schirra (1)	Young Stafford
4	McDivitt Borman	White Lovell
5	Cooper (1) Armstrong	Conrad See
6	Schirra (1) Grissom (2)	Stafford Young (1)
7	Borman White (1)	Lovell Collins
8	Armstrong Conrad (1)	Scott Gordon
9	Stafford (1) Lovell (1)	Cernan Aldrin
10	Young (1) Bean	Collins Williams
11	Conrad (1) Armstrong (1)	Gordon Anders
12	Lovell (1) Cooper (2)	Aldrin Cernan (1)

Number of previous flights in brackets. (–)



LANDING APPROACH. The Apollo 12 lander 'Intrepid' descends towards towards the Ocean of Storms in this striking photograph taken from the command ship 'Yankee Clipper' by astronaut Richard Gordon. Charles Conrad and Alan Bean brought their craft down right on target on 19 November 1969.

later for the crews of Apollo 2/CSM 014. This eventually came on 29 September, 1966 as:

Prime	Schirra	Eisele	Cunningham
Backup	Borman	Stafford	Collins

The launch target for Apollo 1 was officially set as early 1967 but NASA officials and astronauts were aiming for a flight before the end of 1966, possibly in a dual flight with Gemini 12. Deputy Administrator Seamans had stated in January, 1966, [6] "We may even get off a manned Apollo flight before the end of the year" and this was still valid when a NASA official made a similar comment the following May. [7].

Unfortunately, ground testing of Apollo spacecraft 012 progressed very slowly and it became evident that a launch before the close of 1966 was not possible. A launch during the first quarter of 1967 was reaffirmed in an announcement of 28 October, 1966. At the same time, Apollo 2 with CSM 014 was being looked at carefully by the planners. It was intended to be a repeat of the 14-day Apollo 1 mission on the engineering side but with a number of medical experiments (one involved a live frog encased in a small centrifuge!). Even at this stage in Apollo, NASA budgets were under attack and this must have contributed to the downfall of Apollo 2/CSM 014/SA-205 when, on 17 November 1966, it was cancelled as being an unjustified repeat of Apollo 1/CSM 012/SA-204. As Mike Collins commented [8], the 'frog leaped into oblivion'.

As a result, the Schirra and Borman crews were without a mission so the Schirra crew replaced McDivitt's as backup for Apollo 1 and McDivitt's and Borman's were given missions of their own. Further crews were announced on 22 December, 1966, making the schedule appear as:

Apollo 1	Grissom	White	Chaffee
'A' type	Schirra	Eisele	Cunningham
Apollo 2	McDivitt	Scott	Schweickart
'D' type	Stafford	Young	Cernan
Apollo 3	Borman	Collins	Anders
'E' type	Conrad	Gordon	Williams

The reason why Schirra's crew swapped with McDivitt's is unknown but a look at the nature of the missions is instructive. The original Apollo 2 was a simple repeat of a CSM-only flight but with its cancellation in November 1966, it became a very different mission—the first flight of both the LM and Block II CSM. Schirra's crew contained two rookies while McDivitt and Scott were two of the most competent astronauts serving, leading us to the conclusion that McDivitt's crew was considered to be more capable for such a difficult flight as the new Apollo 2. Note, also, the backup crew was highly experienced (five Gemini missions in total). Apollo 3 was intended to fly on the first manned Saturn 5 (SA-503 or SA-504) with the second LM in a type 'E' mission, taking the LM out to large distances from the Earth in a simulated lunar flight.

The move of Stafford from Borman's crew to a command of his own had a major effect on Mike Collins. On the old Borman crew he had been the Lunar Module Pilot (LMP) but Stafford's departure and Ander's selection for the new Borman crew meant Collins had to shift to the position of Command Module Pilot (CMP) because Deke Slayton had a firm rule at the time that a rookie astronaut—Anders in this case—could not be left alone in the Command Module (CM).

Perhaps the reason why Stafford was given his own command was his unexpected command of Gemini 9 instead of Gemini 12 (following the deaths of See and Bassett) whereas when he had been placed in Borman's old crew he had only flown under Schirra in Gemini 6 with his Gemini command still in the future. This is supported by the fact that the eventual commander of Gemini 12, Jim Lovell, had to wait until Apollo 13 before he received a command.

The deaths of See and Bassett in February, 1966 had other consequences, too. Lovell and Aldrin were originally Gemini 10 backups and would have perhaps been assigned to early Apollo crews upon completion of their Gemini duties, eg, Aldrin instead of Eisele or Cunningham in Schirra's crew, thus robbing the historic Apollo 11 of its Armstrong-Collins-Aldrin crew.

It does seem strange that Gordon Cooper was left without an assignment for so long. He commanded the highly successful Gemini 5 but did not apparently make the move along with other experienced astronauts to Apollo training where his experience should have put him in line for a crew of his own. Instead he was forced to mark time in Gemini as Gemini 12 backup and had to wait until 1968 for an Apollo place, the very last of the Gemini astronauts (prime or backup) to receive an Apollo assignment.

Apollo 1 fire

NASA was publicly confident of landing a crew on the Moon before 1970 and, when the first six crews had been named, was hoping for a landing before the end of 1968. However, the cuts in NASA's budget requests—mainly because of the US commitment to Vietnam by President Johnson—left space officials with no illusions. In January, 1966, Deputy Administrator Seamans said [9] the cuts in the FY 1967 budget allowed no funds "for major difficulties that might occur", ie, any major failure would directly cause a slip in the date of the first lunar landing. At that time, the possibility of a major failure had to be acknowledged because neither of the Saturn IB or Saturn 5 launch vehicles had then flown. In June 1966, Apollo Programme Director Sam Phillips made a statement which was later shown to contain a chilling reference: "barring some major setbacks, *some major failure in a static test on the ground* or major failure in flight, it is reasonable to expect that the lunar landing . . . will be accomplished *before the end* of 1969" (authors' emphasis). As history has shown, the setback came not during a dangerous flight aboard a new and untested spacecraft but during a static countdown test on the pad on 27 January 1967 while astronauts Grissom, White and Chaffee were preparing for the flight of Apollo 1 in the coming month. When the severity of the accident became known, Apollo was brought to a sudden halt and put under massive scrutiny to determine the cause. The impact of the findings of the investigations was almost as great as the fire itself—poor workmanship, design and quality control with NASA and North American, the manufacturers, taking equal blame.

Two results of the fire which interest us here were the shelving of the Block I CSM as a manned flight vehicle and the scrapping of all the previously announced astronaut assignments. Deke Slayton said [10] "There's no point in worrying about crew assignments until we know what we're going to do'. The three unmanned flights previously planned for 1967—AS-206, AS-501 and AS-502—would be retained [11].

One month after the disaster, Associate Administrator for Manned Space Flight George Mueller [12] estimated the next manned Apollo flight would be at least 8-10 months in the future, ie, sometime during October to December 1967.

The fire did, in fact, affect the unmanned schedule because the Apollo 1 booster, SA-204, replaced the booster for for the first LM unmanned test, SA-206, because it was the last launch vehicle built with full R & D instrumentation. SA-206 was stored for later use [13]. Even though it was brought back into the schedule after the AS-501/Apollo 4 launch, SA-206 was eventually flown as the launch vehicle for the first Skylab crew.

The first launch of Apollo after the fire was Apollo 4*

in which CM-017 was sent on a high-apogee mission by SA-501, the first Saturn 5. This was a vital flight for Apollo as a whole because it marked the resurgence of confidence in the Apollo concept in the post-fire era. If Apollo 4 had been a failure, either because the spacecreft failed to survive the lunar return speed or because the Saturn 5 failed somewhere in its first flight test, then not only would a further unmanned flight have been necessary but also, more importantly, morale in NASA and the aerospace industry would have fallen even further. In fact, Apollo 4 was a resounding success for both the spacecraft and launch vehicle and it led NASA to confidently announce their flight plans for the next few missions:

1. AS-204 Unmanned LM in Earth orbit.
2. AS-502 Second unmanned Saturn 5 test.
3. AS-206 Second unmanned LM Earth orbit test.
4. AS-205 Schirra flight–first manned Apollo.
5. AS-504 First manned Saturn 5.

AS-204, the flight which had belonged to Grissom, White and Chaffee, became Apollo 5 in January 1968 and AS-502 flew as Apollo 6 in April 1968. AS-206, a planned second unmanned test of the LM in Earth orbit, would have become Apollo 7 on the above schedule but it was included at a time before the first LM aboard Apollo 5 had flown successfully and it was dropped in an announcement of 16 March 1968.

The crew announcement of 20 November 1967 [14] showed the pre-fire crews had been put back into the schedule and Armstrong's crew had made its appearance:

AS-205	Schirra Stafford	Eisele Young	Cunningham Cernan
AS-504	McDivitt Conrad	Scott Gordon	Schweickart Bean
AS-505	Borman Armstrong	Collins Lovell	Anders Aldrin

The McDivitt and Borman crews therefore stayed in their pre-fire positions but the backup crews had moved up a flight and Armstrong, Lovell and Aldrin had come in at the bottom. Conrad has lost his LMP, C.C. Williams, in a flying accident on 5 October and had brought Alan Bean in as a replacement. Bean had served alongside Williams as a Gemini 10 backup.

AS-504 was scheduled to be used by the McDivitt crew in the Apollo 8 mission when LM-2 and CSM -103 would be flown together in a rendezvous and docking mission in Earth orbit by the end of 1968.

AS-505 was slated for Borman's 'E' mission where LM-3 would be taken on a simulated lunar mission. If the second Saturn 5 test, AS-502, proved to be as successful as AS-501 was in November, 1967, then the first manned Saturn 5 (McDivitt) on Apollo 8 would probably be changed to the earlier SA-503. When the post-Apollo 4 schedule was announced in November 1967, NASA Administrator James Webb described the flights of AS-505 to 508 as the lunar landing development flights while AS-509 (which eventually became Apollo 14) would possibly make the first lunar landing attempt in late 1969.

The flight of Apollo 5 with the LM was a success but its launch delay of a few months was ominous for the rest of Apollo because the cause was development problems in the LM itself which resulted in schedule changes almost as drastic as those caused by the fire. Before these changes appeared, Apollo 6 was launched in April 1968 as a second unmanned test of the Saturn 5 but this time the flight was not so successful. The second stage engines shut down early and the third stage failed to reignite in Earth orbit and there was the problem of longitudinal oscillations (the 'pogo' effect) in the whole vehicle. However, engineers were convinced they had the problems fixed and, after a careful review, NASA announced their intention of flying SA-503 as the first manned Saturn 5. There was also a possibility of changing Borman's AS-504 4,000 mile apogee flight to allow his spacecraft to actually loop around the Moon.

After Apollo 6, therefore, the schedule was:

AS-205 *CSM-101*	Schirra's crew
AS-503 *CSM-103* *LM-2*	McDivitt's crew
AS-504 *CSM-104* *LM-3*	Borman's crew

Further crew changes

In the summer of 1968 two changes took place in Apollo, one of personnel and one of flight planning, which left the first six crews looking much as we know them today. On 12 July, 1968 Mike Collins was diagnosed [1] as having a bony growth in his neck pressing on his spinal chord, requiring immediate surgery. Since his neck would be left in a weakened condition for a while after the operation he was removed from Borman's crew and replaced by his backup, Lovell, who in turn was replaced in Armstrong's crew by Fred Haise,the first group five astronaut to be assigned to a crew. Haise became LMP and Aldrin was 'promoted' to CMP.

The second change takes us back to the problems of the LM. Development difficulties meant that Borman's LM-3 would not have been ready until spring, 1969 and McDivitt's LM-2, which was supposed to be ready first, was overweight and even further behind schedule. In order to prevent a gap of half a year between Schirra's Apollo 7 and the next flight, NASA had to take drastic action. The obvious solution was to fly a second CSM without a LM to give time for LM-3 to be completed but planners did not want a repeat of Apollo 7. The answer was to send a CSM on a lunar-orbiting mission. As the next crew in line, McDivitt was offered the chance of this flight but, probably because he wanted to keep a LM, he turned it down and Borman's crew got the chance to become the first men to orbit the Moon. The crews swapped over in the schedule, taking their backup crews with them, and LM-2 was dropped altogether:

Apollo 7 *CSM-101*	Schirra Stafford	Eisele Young	Cunningham Cernan
Apollo 8 *CSM-103*	Borman Armstrong	Lovell Aldrin	Anders Haise
Apollo 9 *CSM-104* *LM-3*	McDivitt Conrad	Scott Gordon	Schweickart Bean

William Anders was unhappy about the change because he was now a LM pilot on a flight with no LM. Another effect, although not apparent at the time of the changes, was more historic. As with the Gemini programme, a backup

* *Prior to the fire it was intended to give Apollo numbers to manned flights only but afterwards unmanned flights were included, beginning with Apollo 4.*

crew could expect to skip two missions and then become prime crew of the third. Before the changes, the crew of Apollo 11 would have been Conrad, Gordon and Bean but afterwards it became Armstrong, Aldrin and Haise. The public was told in an August announcement that Borman's crew was training for an Earth orbit mission but at a press conference on 23 September, NASA said allowances had been made for a possible circumlunar flight, with the decision to be made after a review of the Apollo 7 mission results. Confirmation came on 12 November.

A successful flight for Apollo 7 was clearly needed to restore hope of a lunar landing before the end of the decade. If Apollo 7 had failed in some important way—with engine or environmental systems problems, for example—a repeat flight would have been necessary and we may have seen Apollo 12 make the first landing, following a similar route to that planned before LM delays forced schedule changes. Schirra said Apollo 7 would fly when the spacecraft was ready and any testing or modification delays would have to be accepted, although soon after the fire it had been hoped to deliver CSM-101 to the Cape in late 1967 for a launch in March 1968 [15]. The crew and its backup had been named on 9 May 1967 when NASA was hoping for 3 to 4 Saturn 5 launches in 1968 and up to 6 launches in 1969. By February 1968, a much-reduced FY 1969 budget prompted NASA Administrator Webb to say the Apollo schedule had been stretched so far that every Saturn 5 flight would have to be successful if a lunar landing was to be achieved before the end of 1969. The tight scheduling was reflected in the April 1968 recommendation to fly SA-503 in late 1968 as the first manned Saturn V booster instead of leaving it as an unmanned test (McDivitt's crew was then still planned to fly first after Apollo 7).

Manned Apollo Successes

The first hurdle to be overcome before a 1969 lunar landing could be achieved was the testing of the CSM in Earth orbit by Apollo 7. Following splashdown on 22 October 1968, Apollo Programme Director Sam Phillips described the flight as "A perfect mission. I don't think there's been one that's been as successful" [16]. The eight successful burns of the main engine demonstrated the system's reliability and allowed NASA planners to change Apollo 8's flight plan to include circumlunar flight. The tentative schedule for Apollo thus became.

Apollo 8	21-27 Dec	1968	'C-prime'
Apollo 9	March,	1969	'D'
Apollo 10	June,	1969	'F'
Apollo 11	autumn,	1969	probable landing
Apollo 12	winter,	1969	

The Apollo 10 crew was announced on 13 November, 1968 as [17]:

Prime	Stafford	Young	Cernan
Backup	Cooper	Eisele	Mitchell
Support	Engle	Irwin	Duke

but the decision still had to be made whether the mission would be Earth-orbiting ('E'-type) or circumlunar ('F'-type). The 'F' decision was announced formally on 27 December 1968 after the success of Apollo 8 when plans for Apollos 9 and 10 were finalised. There had been a possibility, *albeit* a small one, that Apollo 10 would make the first landing attempt.

Astronaut Irwin has said [18] Stafford knew by the spring of 1968 that he would be Apollo 10 commander.

The backup crew is interesting because its selection made it eligible to fly aboard Apollo 13 and Cooper would at last travel into space in Apollo. Eisele had just returned from space aboard Apollo 7 and was clearly given the position of CMP backup because of his experience. Since the Apollo 10 announcement was made so soon after Apollo 7 it is feasible Eisele knew before his first flight that he would get onto the new crews. Mitchell was the second group 5 astronaut to be assigned to a crew.

When Apollo 8 returned from the Moon after Christmas, 1968 there still remained the dual flights of the LM and CSM to be achieved but the first two manned flights had shown the superb abilities of post-fire Apollo. Public, political and engineering confidence was reaching a peak which will probably never be equalled and the Soviets seemed to be firmly in second place in the space race.

In contrast to Apollo 8, the public regarded the Earth-orbiting flight of Apollo 9 as a rather ordinary mission but NASA knew it was one of the most vital missions it had ever undertaken. In an Apollo 9 press briefing at NASA HQ during 31 January, Apollo Programme Director Hage made it clear that Apollo 9 was a very complicated and important mission which had to be successful for the lunar landing schedule to go ahead and that if there were any need for a repeat mission then Apollo 10 would fill the gap. This would, of course, have meant that Apollo 11 would have been pulled away from the first lunar landing mission to be replaced by Apollo 12. Despite earlier crew changes, Pete Conrad would once again have become prime candidate to be the first man on the Moon!

Of course, Apollo 9 with astronauts McDivitt, Scott and Schweickart became yet another outstanding success for Apollo, allowing the rest of the programme to go ahead with full confidence. On 25 March 1969, NASA confirmed Apollo 10 would be a 99% dress rehearsal for the actual landing, taking Stafford and Cernan to within 10 miles of the lunar surface in their LM, 'Snoopy'. In February, 1968, the Apollo Site Selection Board's five safety-first landing sites had been announced [19] and Apollo 8 had been able to observe site 1 in great detail. Apollo 10, on the other hand, would be able to concentrate mainly on sites 2 and 3.

Hours after Stafford, Young and Cernan had reunited the LM ascent stage with CM 'Charlie Brown', NASA knew the way to landing on the Moon was open and announced [20] the lunar landing time of Armstrong and Aldrin in LM-5 as 19.22 BST on 20 July 1969. Photographs returned from Apollo 10 confirmed site 2 in the Sea of Tranquility as the most suitable landing area.

Incidentally, Apollo 10 was the first mission in Mercury, Gemini or Apollo which carried astronauts who had all flown before in space. Apollo 11 was the second and, so far, only other mission which did not contain a rookie.

When the crew members of Apollo 11 were selected, noone among them was certain he would be aboard the first landing flight because there were still many unknowns to be overcome during Apollos 9 and 10. After serving as backup crew to Borman, Lovell and Anders on Apollo 8, their selection was not automatic in this case because Mike Collins had fully recovered from his spinal operation and was waiting for a crew. Buzz Aldrin recounts [21] how the final crew of Apollo 11 came together:

Table 4. Command Module Pilots—Commanders.

CMP		Cdr	
Apollo 8	Lovell	Apollo 13/14	Lovell
Apollo 9	Scott	Apollo 15	Scott
Apollo 10	Young	Apollo 16	Young
Apollo 11	Collins	Apollo 17	Cernan (Collins)
Apollo 12	Gordon	Apollo 18	(Gordon)

"Neil and I, because we had backed up Apollo 8, were by now quite certain we would fly Apollo 11, but we did not know who the third man would be. Fred Haise would probably be rotated out of our flight and Mike's bad neck had left him in a kind of assignment limbo. Neil and I agreed that we wanted Mike on our flight. Mike said he wanted it, too. Neil made an appropriate hint to Deke Slayton, and we were sure pleased when his decision matched our desires."

Collins joined the Armstrong crew in December 1968 and on Monday 6 January 1968, the crew was called into Deke Slayton's office in Houston and told it would attempt the first lunar landing, with Apollo 11. The prime and backup crews were made public during 9 January:

Prime	Armstrong	Collins	Aldrin
Backup	Lovell	Anders	Haise

The historic Armstrong Apollo 11 crew had arrived at its final form via Armstrong-Lovell-Aldrin and Armstrong-Aldrin-Haise but the order of events which took Haise out of the crew is in doubt because, as we have seen in the extract above, Aldrin claims Haise was moving from Armstrong's crew anyway before Collins was picked by Armstrong and his LMP while Collins has written [1] that Haise was 'bumped' out by his arrival.

The truth is a combination of the two: Slayton was moving Haise out anyway, with a view to including Collins later because Collins had been unfortunate to lose Apollo 8 [22]. We must also note Aldrin would have welcomed Haise's departure since it allowed him to regain his LMP place and possibly reach the surface of the Moon. The shifting of flight assignments showed itself in the CM seating arrangements. Armstrong, as commander, occupied the left hand seat. Usually the centre seat was occupied by the CMP and the right hand seat by the LMP* which meant Aldrin as LMP should have flown on the right hand side. However, since he had trained as CMP when Haise had been on the crew and Collins had not arrived until much later, he flew in the centre couch for launch.

Borman had decided to step down and Jim Lovell was promoted to commander of his own crew while Anders was 'promoted' to CMP in order to leave a convenient space for the 'bumped' Haise to occupy. As backup crew to Apollo 11, Lovell's team was eligible to fly aboard Apollo 14.

Of course, the achievements of Apollo 11 in July 1969 are well known to readers of *Spaceflight* and it would be a waste of space to go into them in detail here but there are some interesting side issues:

1. If any one of the prime Apollo 11 crew had not been fit for a 16 July launch he would not have been replaced by his backup. Instead, the launch date would have been slipped to allow the prime crew to reform because it had received unique training and was more competent for such a difficult mission;

2. On the morning of 16 July, NASA Administrator Tom Paine told all three astronauts [21] that if Apollo 11 had to be aborted he would disrupt the crew schedules and put them on the next flight.

Before the flight, Deke Slayton told Mike Collins [1] he wanted to put him in a later mission and Collins claims this would have resulted in him commanding Apollo 17 and walking on the Moon. How believeable is this claim? Table 4 shows Collins would have commanded Apollo 17 if he had not retired because the CMP of a particular flight was experienced and senior enough for another mission six flights later. Lovell flew as a commander five missions later because the Apollo 13 and 14 crews swapped over (*see later*) and Gordon was almost certain to command Apollo 18 because he had been backup commander of Apollo 15. It fits the pattern, therefore, if we assume Cernan, previously the Apollo 10 LMP, was picked to command Apollo 17 because Collins was not available.

Apollo 12 and after

The world applauded the unique achievement of Apollo 11 while the mission was still underway and for a short time afterwards but when the later, more scientifically important missions were launched, public interest dropped dramatically. NASA fought to keep every mission but even so it lost three and was forced to stretch out the landing schedule. In January, 1969 Apollo 13 was scheduled to fly in the latter part of that year.

The crews for Apollo 12 were announced on 10 April 1969 [23] while the Apollo 11 crews were beginning their intensive training:

Prime	Conrad	Gordon	Bean
Backup	Scott	Worden	Irwin

At the time of their selection, Conrad and Bean stood a chance of becoming first men on the Moon because no-one was sure of the success of Apollo 11. If all went well with Apollo 11, however, NASA planned a landing by Apollo 12 some four to six months later.

The mission patch of the Apollo 12 crew had one interesting aspect. C.C. Williams had originally been LMP for Conrad but his death on 5 October 1967 in a T-38 crash led to Alan Bean stepping up to the flight crew. In memory of Williams, Bean suggested their crewpatch should contain a fourth prominent star to represent the deceased fourth member of the team.

The backup crew of Scott, Worden and Irwin became eligible to fly Apollo 15 and it can be seen to contain two rookies, the first time this had happened since Schirra's crew had been backup to Grissom's crew on Apollo 1. The relaxation of Slayton's no-rookie-CMP rule stands to show that either NASA believed the more difficult engineering aspects of landing on the Moon would be fully understood by the time of Apollo 15 or they were prepared to take risks to allow most of the group 5 astronauts to fly.

Apollo 13 and 14 crews named

After the safe return of Armstrong, Collins and Aldrin in July 1969, NASA was able to plan a pinpoint landing for Apollo 12 in the November and to announce the crews for two later missions—Apollos 13 and 14. If we base the flight crews on the backup teams for Apollo 10 and 11, we would expect them to be:

Apollo 13	Cooper	Eisele	Mitchell
Apollo 14	Lovell	Anders	Haise

However, the announcement of 7 August, 1969 showed [24]:

Apollo 13	Lovell	Mattingly	Haise
Apollo 14	Shepard	Roosa	Mitchell

There are two differences to be considered here:

1. The crews appear to have changed missions.

2. Cooper, Eisele and Anders have apparently been replaced by Shepard, Roosa and Mattingly, respectively.

* *This could be the reason why NASA always announced the crews in commander-CMP-LMP order.*

Shepard was grounded in 1963 after it was discovered he was suffering from Meniere's disease, a build up of pressure in the inner ear with symptoms of deafness and failing balance. The deafness continued to increase until he submitted to an operation in 1968 to relieve the pressure and on 7 May 1969 NASA announced he was back on the active astronaut list. Shepard made the recommendation that he be considered for a mission. The next available was Apollo 13 but Gordon Cooper was eligible to command it after having served as Apollo 10 backup commander. It has never been fully explained why Cooper stepped down from flying status but it could be that he was either going to be moved to a later flight or lost from Apollo altogether in order to allow Shepard to step in and he was unwilling to accept the move. Another possibility is that Cooper was asked to serve under Shepard in the Apollo 13 crew and he refused.

The exchange of Apollo 13 and 14 crews did obviously occur and almost certainly the reason behind it was the inclusion of Shepard. He had only 15 minutes experience of spaceflight, had never flown in orbit and had not trained for a flight in six years, so it is not surprising the unofficial explanation for the swap is Shepard's inability to master Apollo in time to command Apollo 13. An article first published in 1970 noted [25]: "One version from good sources is that Shepard was having difficulty in training, specifically with the lunar module simulator with which Moon landings and take-offs are practised, and needed more time. Deke Slayton, it was strongly rumoured, was under pressure from NASA Headquarters to do something about it, including the possibility of dropping Shepard altogether. For Slayton, convinced of Shepard's high competence, that would have been unthinkable. "Al has been in training longer than anyone else we've got", says Slayton, "If he's not qualified, nobody is".

MOONWALK. Apollo 14 commander Alan Shepard assembles a tool as he stands beside the Modularised Equipment Transporter (MET) on 5 February 1971.

The loss of Anders and Eisele to the crews is more difficult to explain because neither Mattingly nor Roosa had any prior claim to the CMP positions. Perhaps NASA wanted the change to two group 5 astronauts per crew to be made early because it was becoming apparent that Apollos 18 and 19 could be cancelled. Table 5 illustrates the change in crew composition from Apollo 13 onwards.

In Anders' case, though, it could be that he was not willing to fly yet another mission without piloting a LM. Remember he was very disappointed as a LMP when Apollo 8 lost its LM in 1968 and now he was being offered the position of CMP.

The backup crews were announced as:

Apollo 13	Young	Swigert	Duke
Apollo 14	Cernan	Evans	Engle

NASA said Apollo 13 would attempt a landing at *Fra Mauro* if Apollo 12 was successful in achieving a pinpoint landing and if the photographs of the area returned by Conrad's crew showed up no problems. Launch was set for 12 March 1970. On 8 January 1970, however, the launch was deferred to 11 April to allow more time for detailed and specific mission planning although there was probably a connection with a general stretching of Apollo from three to two missions per year, announced on 4 January [26]. The Apollo 14 team had been training for a mid-1970 landing at Littrow but were now shifted to a 30 September launch date.

During the final six-day countdown for Apollo 13, the crew came into contact with measles and Mattingly was unfortunately not immune to them. Backup CMP John Swigert stepped into the prime crew a mere two days before the 11 April launch target. If he had been unable to show he was up to prime crew standards or if the contact had occurred a day or two later, the launch would have been postponed until at least 9 May, the next launch opportunity.

When Apollo 13 failed to reach its lunar destination because of the explosion of an oxygen tank in the Service Module, the Littrow training for Apollo 14 was stopped. On 7 May, 1970, NASA showed it considered *Fra Mauro* a very important target by rescheduling Apollo 14 to land there, with a launch date no earlier than 3 December, 1970. Investigations and modifications to all the Apollo spacecraft slipped the date into 1971.

Curiously, Colonel Edwin Aldrin, father of Buzz Aldrin and a NASA safety consultant, had suggested [27] that

Table 5. Apollo astronauts' groups and flight records.

				Group	Flights
Apollo 7	Schirra	Eisele	Cunningham	1-3-3	2+0+0=2
Apollo 8	Borman	Lovell	Anders	2-2-3	1+2+0=3
Apollo 9	McDivitt	Scott	Schweickart	2-3-3	1+1+0=2
Apollo 10	Stafford	Young	Cernan	2-2-3	2+2+1=5
Apollo 11	Armstrong	Collins	Aldrin	2-3-3	1+1+1=3
Apollo 12	Conrad	Gordon	Bean	2-3-3	2+1+0=3
Apollo 13	Lovell	Swigert	Haise	2-5-5	3+0+0=3
Apollo 14	Shepard	Roosa	Mitchell	1-5-5	1+0+0=1
Apollo 15	Scott	Worden	Irwin	3-5-5	2+0+0=2
Apollo 16	Young	Mattingly	Duke	2-5-5	3+0+0=3
Apollo 17	Cernan	Evans	Schmitt	3-5-4	2+0+0=2
ASTP	Stafford	Brand	Slayton	2-5-1	3+0+0=3

NASA should postpone the November 1969 launch of Apollo 12 and fly Apollos 12 and 13 together so the crews could rescue each other in case of emergency. NASA considered the proposal impractical and said rescue from lunar orbit was "out of the picture for Apollo".

The success of Apollo 14 proved once again how NASA was able to recover from a serious setback.

Apollo 15 and the 'J'-missions

By late 1969, Scott, Worden and Irwin had been notified [18] they would be the Apollo 15 prime crew. The official announcement came on 26 March 1970 and showed the backup crew was Gordon, Brand and Schmitt, who would therefore become eligible to fly aboard Apollo 18. Schmitt thus would probably become the first scientist/astronaut to be given a lunar mission. Just over five months later the announcement came that Apollos 18 and 19 were cancelled (*see later*), meaning the backup crews from Apollos 15 and 16 would have no prime mission assignment. The scientific community had long been complaining about the lack of scientist astronauts on lunar flights and Irwin says [18] there was considerable pressure put on NASA to replace him with Schmitt but Slayton, Shepard and his misison co commander stood by him. Irwin was an obvious choice as a LMP because he had a vast knowledge of the LM from working closely with the Grumman engineers during its development and testing.

Cancellation of Apollos 18 and 19 had a profound effect on Apollo 15 because the ultimate scientific sophistication of Apollo, the 'J' mission, was now in danger. To salvage it, Apollo 15 became a 'J' and carried a Lunar Roving Vehicle (LRV) to the Moon but the problem was that LM-9, initially assigned to Apollo 15, could not carry a LRV. It was therefore replaced by LM-10. Similarly, the CSM had to be 'J'-configured but CSM-111, the next in line for flight, was an 'H' vehicle. CSM-112 was flown instead.

The landing site of Apollo 15 was confirmed as Hadley Rille on 10 January, 1971 and it proved visually to be the most exciting site visited during the programme. At the time of the crew announcement in March, 1970 the site selected was Littrow.

Apollo 16 and 17

In the Apollos 18 and 19 cancellation announcement of September, 1970, tentative launch dates of January and June 1972 were assigned to Apollo 16 and 17, respectively, with crews and targets to be given later. The prime crew of Apollo 16 was easily predicted as Young, Mattingly and Duke because both Young and Duke had served as Apollo 13 backups and Mattingly had been replaced by Swigert on the crew becasue of the measles contact, so it was logical and fair for him to fly aboard Apollo 16.

The crews were announced on 3 March 1971 as:

Prime	Young	Mattingly	Duke
Backup	Haise	Roosa	Mitchell

The choice of backup crew had lost its significance by now because the 18 and 19 cancellations meant there was one flight only after 16. If 19 had been intact we can be certain neither Roosa nor Mitchell would have been on the Apollo 16 backup team, although Fred Haise would probably have remained as commander.

Interest in a *Descartes* landing site went back as far as Apollo 12 but it was a set of detailed photographs returned by Apollo 14 which persuaded NASA to give the final go-ahead on 17 June 1971 for a *Descartes* landing in March, 1972.

Unfortunately, Charles Duke was admitted into hospital with pneumonia in January, 1972 [28] at a time when the crew should have been in intensive training but, luckily for them, several hardware problems forced a launch date slippage of one month to 16 April. If the problems had not arisen it is hard to say whether Duke would have been able to catch up on his lost training but if he had been replaced by Mitchell it is likely he would not have gone to the Moon at all.

APOLLO 16 TRAINING. Astronaut Charles M. Duke, Jr., lunar module pilot, tries out equipment for the soil mechanics experiment (S-200) during extra-vehicular activity training at the Kennedy Space Center. An Earth-adapted model of the Lunar Roving Vehicle (LRV) is in the background. Nearby is astronaut John W. Young, commander of the Apollo 16 mission.

NASA

Shortly after the astronauts of Apollo 15 splashed down in the Pacific, the crews for possibly America's last mission to the Moon in this century were named as:

Prime	Cernan	Evans	Schmitt
Backup	Scott	Worden	Irwin

Cernan and Evans had served as Apollo 14 backups but Schmitt had served as backup LMP on the mission which had just ended, Apollo 15. Pressure from the scientific community finally payed off in getting a scientist aboard a Moon-bound flight but we must sympathise with Joe Engle who was pushed aside to make it possible. He probably knew during his Apollo 14 backup duties that he would not be aboard Apollo 17 and that his Apollo work would be finished after Apollo 14 was launched in January 1971.

The Apollo 17 backup crew was simply the Apollo 15 prime crew assigned *en bloc* in order to save unflown group 5 astronauts having to learn the systems up to misison standards. The backup team, though, did provide the press with some entertainment because of the "great Apollo 15 stamp scandal".

The Apollo 15 astronauts had carried 398 unauthorised postal covers in their Personal Preference Kits aboard the spacecraft and some had later appeared for sale in Europe [29]. NASA was very sensitive about possible commercialisation of its flights and clearly wanted the astronauts to

step down as Apollo 17 backup members and it was Irwin who made the first move by retiring from NASA. Unofficially, the astronauts received only formal reprimands but as soon as Irwin left, Scott and Worden were dropped [18]. The men privately agreed to take equal blame for the incident although Irwin has said [18] he was reluctant to agree to Scott's proposals in the first place but that "I felt if I gave him too hard a time over this thing, he might decide to take Jack Schmitt instead". This is clearly a reference to the pressure on NASA to fly Schmitt to the Moon aboard Apollo 15.

Thus the backup changes for Apollo 17 were announced on 23 May 1972 [30], effective from 1 July, as: Scott, Worden, Irwin changing to Young, Roosa, Duke.

Mattingly had requested that he be allowed more time with his family, so he was replaced in Young's team by Roosa, who had just become available following his duties as Apollo 16 backup CMP.

We thus come to the end of the lunar crews and we can now take a look in the next section at the programme as a whole.

Crewing Policy Reviewed

The most important influences on the selection of Apollo crews were undoubtedly those of Deke Slayton, director of flight crew operations, and Alan Shepard, chief of the astronaut office. Both had been taken off flying status early in the manned space programme and given senior positions close to the rest of the astronauts and so were in unique positions to pick men for missions. After the MSC Director Robert Gilruth had endorsed each crew, the names were then sent onto NASA Associate Administrator George Mueller in Washington, D.C., for final approval. Slayton has said [31] NASA had never rejected any of his recommendations and "There isn't any big magic selection that goes on for each mission. You've got a mission to do and you've got so many flights to fly and you assign guys to fly them. Sometimes you ask the commander about the composition of his crew. We know who gets along and who doesn't. If you've got other options, sometimes you give the commander a choice of three or four guys. Sometimes you don't have any choice. We've never pulled a man because of any personality conflict."

Table 5 presents us with very clear evidence of Slayton's crewing policy for the Apollo astronauts as a whole. Up until Apollo 13, group 1 and 2 astronauts assumed command, with mainly group 3 men filling the other positions. After Apollo 12, group 5 astronauts filled the CMP and LMP posts, with the exception of Schmitt (group 4), who took over the place of Engle (group 5). Commanders were by now ex-early Apollo crewmen.

Listing the flight record of each crewman in Table 5 shows how Apollo 10 stands out as the most experienced crew. Does this lend support to the theory that Apollo 10 was perhaps privately favoured by NASA as the first lunar landing flight? Unfortunately, it does not. Remember the first six crews were formed in 1966 so if we tabulate their flight records by the end of Gemini we get (adding the seventh crew):

Apollo 1	Grissom	White	Chaffee	2+1+0=3
Apollo 2	McDivitt	Scott	Schweickart	1+1+0=2
Apollo 3	Borman	Collins	Anders	1+1+0=2
Apollo 4	Schirra	Eisele	Cunningham	2+0+0=2
Apollo 5	Stafford	Young	Cernan	2+2+1=5
Apollo 6	Conrad	Gordon	Williams	2+1+0=3
Apollo 7	Armstrong	Lovell	Aldrin	1+2+1=4

The original Armstrong crew was almost as experienced as Stafford's so we can deduce that the first landing crew was hoped to be Stafford's, Conrad's or Armstrong's, even though we are talking about 1966 when NASA was publicly saying that a large number of lead-up missions might be required.

Returning to Table 5, we can see how badly inexperienced was Shepard's Apollo 14 crew—more so than Schirra's. It was the only crew in the entire Apollo programme which contained no astronauts experienced in orbital flight. This suggests that Shepard's crew *was* originally slated for Apollo 13 but had to slip to Apollo 14 because of training difficulties.

A curious anomaly in the first crews is the composition of Schirra's crew. His was the only team with two rookies at a time when a complex engineering mission could be expected. This means that either Slayton's rule of a backup crew becoming a prime crew two missions later did not exist at the time or that Schirra was going to lose either Eisele or Cunningham. The Apollo fire meant we did not find out because Schirra was given the no-LM Apollo 7 mission where two rookies were acceptable. The explanation could be that since the crew was at first intended to fly CSM-014 (a repeat of CSM-012) Slayton was taking a chance in giving two rookies flight experience in a relatively easy mission. When 014 was cancelled, it put Slayton in difficulties so he made Schirra's crew backup to Grissom's. The fire then solved his problem but we are left with the impression that, had Grissom's crew survived, the Schirra crew would have been changed.

The story of the actual selections for the lunar Apollos is complete but we must now look at the histories of Apollos 18 to 20 and how they might have been manned. At the same time, we shall look at Skylab since there are strong links between the two areas.

Skylab and Apollos 18-20

In November 1967, Administrator Webb said that AS-509 (which became Apollo 14) would possibly be the first lunar lander. These were the days before the NASA budget suffered harsh cutbacks and in 1968 NASA asked Rockwell for proposals for CSMs 116-119. These would have flown as:

CSM 116.......	Apollo 19	(in reality Skylab 2)
CSM 117.......	Apollo 20	(Skylab 3)
CSM 118.......	AAP	(Skylab 4)
CSM 119.......	AAP	(Skylab rescue)

Skylab had its origins within the Apollo Applications Program (AAP) which was set up to use the post-lunar Apollo equipment in long duration Earth orbital flights for scientific, technical and engineering missions. The Apollo Applications Office was set up in August, 1965, long before the first manned Apollo had flown. There were many proposals to use the excess equipment but they were either rejected or merged with others to produce what we know today as Skylab. For example, a 1966 plan called for four launches, two carrying three men each and two to provide a 'wet' workshop and Apollo Telescope Mount. The 'wet' workshop, which required astronauts to fit out the spent S-IVB second stage of a Saturn IB for inhabitation, remained as the official target until NASA announced a few days after the successful landing of Apollo 11 in July 1969 that a 'dry' workshop would be used.

This was significant for the rest of Apollo. A 'dry' workshop could not be launched by the Saturn IB but had to use the Saturn V and since all the Saturn Vs ordered were already slated for lunar Apollos then Apollo 20 had to be cut. Launch would be sometime in 1972. It is interesting to note the announcement was made *after* the first lunar landing. If Apollo 11 had failed then probably no such announcement would have been made because the Apollo 20 mission might have been required to achieve the first lunar landing. This objective was, before all else, the aim of Pro-

David Baker made an interesting suggestion [34] to launch Skylab B in 1978 with crew visits from the US and USSR extending to 1979, after which one of the first Shuttle missions would pay a visit. Crew predictions are difficult because of the four-year gap following the last Skylab A mission and because the Shuttle would have been demanding such a great deal of attention from the astronauts. Some of the experienced Skylab astronauts might have been reluctant to continue in such a dead-end project while others were working on the next programme (the same sort of feeling crept in with the final Gemini flights).

An even more daring plan was put forward in 1970 by McDonnell engineers [35] who proposed a *lunar* orbiting Skylab launched by two Saturn Vs in the mid-1970s.

ASTP

The desirability of flying a joint mission with the USSR had interested US scientists and engineers long before the ASTP agreement was signed in May 1972. Their interest was in maintaining the momentum of American manned spaceflight at a time when budgetary restraints was forcing NASA to cut lunar missions, yet the engineers were able to tempt politicians into providing money for a flight which had little scientific value. ASTP was political in origin and political in execution.

In October, 1969, Soviet space scientist Oleg Gazenko had suggested [36] that a cosmonaut could be included in an Apollo lunar landing crew. Two years later it was reported [37] US scientists had suggested a joint US-USSR lunar flight, in an effort to get Apollos 18 and 19 reinstated. There was little surprise, therefore, among space circles when ASTP was announced. Despite the irrelevance of ASTP to the development of spaceflight, *any* new American misison would have been welcomed with open arms.

Predicting the US crew for such a mission is fairly simple because of the few astronauts left without space experience at the time. A rendezvous-experienced commander was obviously required and, as was noted in the Skylab paragraphs, Stafford was the best in this field and had curiously been left out of a Skylab command position. The other two places aboard Apollo seem as simple to fill. Brand and Engle had been unfortunate not to fly to the Moon and Brand had served as a Skylab backup commander, so we can predict the US crew with some confidence:

Commander:	Stafford
CM pilot:	Brand
Docking Module pilot:	Engle

We are missing one vital point. Deke Slayton, after being grounded with a heart problem during Project Mercury, was restored to flight status in March 1972. At the age of 48 he was too old to wait for the Shuttle and ASTP must have seemed his last chance to fly in space. Together with the fact that he was chiefly responsible for deciding crew composition, it was concluded very early on [38] that he would almost certainly fly ASTP.

The NASA Administrator mentioned on 4 April 1972 [39] that both Stafford and Slayton (plus Swigert) were already studying Russian.

The US crews for ASTP were announced by NASA on 30 January, 1973 as:

Prime	Stafford	Brand	Slayton
Backup	Bean	Evans	Lousma
Support	Truly, Overmyer, Crippen, Bobko		

It is interesting to speculate on the fate of Engle had Slayton remained grounded. In our prediction we included Engle because of his seniority but remember he was passed over for every Skylab crew despite his loss of the Apollo 17 LMP position to Schmitt. He may, therefore, have been excluded from ASTP anyway.

There is nothing remarkable about the backup crew. They all had considerable experience and were taking dead-end jobs (just as Young, Roosa and Duke had done with Apollo 17).

We can be sure that group 6 scientist/astronauts were not pleased about the fact that all the support team members were group 7 (ex-MOL) astronauts who had been added to the NASA ranks in August 1969.

We have come to the end of our review of the Apollo programme and astronaut selection but there are still some interesting questions to be asked.

Apollo 1 fire

Let us suppose the Apollo 1 fire never occurred and that Grissom's crew flew the first manned Apollo. How would Project Apollo have developed from that beginning? An immediate reaction would be to bring the date of the first lunar landing forward to mid-1968 at the latest, but that would ignore a number of pertinent facts unconnected with the fire. As we have seen, the LM was far behind schedule and *that alone* was enough, as Mike Collins [1] has said, to ensure the 'G' mission would have had to wait until mid-1969 anyway.

Following our hypothetically successful Apollo 1 mission in February 1967, we come to a long gap before the next manned flight is possible because we have to wait for three unmanned flights to be launched (we know them now as Apollos 4, 5 and 6) to test the Saturn V and LM. Because the LM is not ready for McDivitt in 1968, Borman's crew flies around the Moon in December 1968 as Apollo 2 and the LM is eventually tested out during the Apollo 3 mission in 1969. The December 1968 launch of Apollo 2 (post-fire designation: Apollo 8) is highly debatable. Since no delay-producing LM is involved it could well fly by September 1968 but unless NASA goes to Congress for a great deal of money for a LM crash programme we will have to wait until March 1969 for the first manned LM flight and leave large gaps between the first three manned missions.

The crew situation in December 1966, just before the fire, was:

Apollo 1	Grissom	White	Chaffee
	Schirra	Eisele	Cunningham
Apollo 2	McDivitt	Scott	Schweickart
	Stafford	Young	Cernan
Apollo 3	Borman	Collins	Anders
	Conrad	Gordon	Williams

In our hypothetical case, Mike Collins is replaced by Richard Gordon when he steps down from Borman's team and not, as in reality, Lovell from Armstrong's crew, the first crew introduced after the fire.

Now we come to some significant departures from reality. Since the Schirra crew acted as Apollo 1 backup they are now eligible for the Apollo 4 mission when the LM is to be tested in a lunar orbital flight. But we have a problem: Deke Slayton has a firm rule that a rookie cannot be left alone in the CM in these early days of Apollo. Clearly we cannot allow Eisele to pilot a CSM around the Moon on his first flight so we must replace him with Collins as CMP in order to provide the quantity of experience the crew needs for such a highly complicated mission.

With the swap of Borman's and McDivitt's crews because of the LM delays, Conrad's crew now becomes Apollo 11 prime but we have a problem because we have already lost CMP Gordon. It is still too early to being in rookie Eisele as CMP so we introduce the man who actually became the

first new CMP after the fire, Jim Lovell. Thus, the historic Apollo 11 lunar landing crew is now Conrad, Lovell and Bean. Table 7 presents the results of this and the other deductions.

Apollo 12 is now manned by Stafford, Young and Cernan.

The crew of Apollo 13 is easy to predict with this line of reasoning because Armstrong's team was the next to be actually introduced, although we have now lost Lovell to A Apollo 11. With Apollo 13, however, we can bring Eisele back in as a CMP (the real Apollo 13 had a rookie CMP).

The choice of Apollo 14 remains unaffected by there being no fire becasue Shepard still 'elbows' his way into the schedules at the same time as he did in reality. His crewmates will perhaps remain as Roosa and Mitchell since he and Slayton make the decisions on selections but Haise was one of the best group 5 astronauts so it is reasonable to put him in Shepard's team as CMP and drop Roosa to a later flight.

Things now become more complicated because we still have astronauts Grissom, White and Chaffee with no lunar assignments, yet history shows us that certain members of the real crews did fly again as commanders—we know Apollo 8 CMP Lovell became commander of Apollo 13; Apollo 9 CMP Scott became commander of Apollo 15; Apollo 10 CMP Young became commander of Apollo 16, and Apollo 10 LMP Cernan became commander of Apollo 17. We must conclude, therefore, that of the Grissom crew, White should certainly fly again and Chaffee stands a chance of doing so. Grissom is not given a landing crew because this is what happened to the commanders of Apollos 7 to 10 in reality. This means White will receive command of Apollo 15 because of his seniority, possibly taking Chaffee with him as LMP. Similarly, the commanders of Apollos 16 and 17 will be Gordon and Scott, although we cannot say they will take Anders and Schweickart with them (they have already flown technically-demanding missions but Chaffee has not).

It is feasible that Apollo 18 could have been flown if the fire had not occurred and, in that case, Mike Collins becomes prime candidate for commander.

Of course, all this hypothetical scheduling will be altered if NASA had decided to fill the gap between Apollos 1 and 2 by flying a repeat of the Apollo 1 mission but with a B Block II CSM. We must acknowledge there is a good chance that would have happened.

What if See, Bassett and Williams had lived?

If See and Bassett had not died in their T-38 crash of 28 February 1966, they would have gone into the Apollo crew schedule by one of two routes:

1. The commanders of the first six Apollo crews (Grissom, Schirra, McDivitt, Stafford, Borman and Armstrong) came from the Gemini prime crews immediately prior to See's, so if See and Bassett had been transferred directly to Apollo after their Gemini 9 flight they would have occupied the position which was actually taken by Conrad and Gordon, ie, Apollo 12.

2. The more likely route would have involved serving as backup to the Gemini 12 crew (Table 8) of Stafford and Cernan before moving on-to Apollo. Bean, Armstrong, Anders and Cernan followed a similar route by serving on dead-end Gemini backup crews. They would then have been assigned to the Apollo team immediately after Armstrong's, ie, Apollo 12, forcing Conrad and Gordon to drop to Apollo 13. If Williams had survived his accident he would have flown in Conrad's crew instead of Alan Bean.

It cannot be doubted that See, Bassett and Williams would have flown in Apollo had they survived simply because every other Gemini astronaut, prime or backup, made it onto an Apollo mission.

It is very difficult to predict what form the Apollo crews would have taken if Grissom, White, Chaffee, See, Bassett and Williams, had all survived but we can make the attempt by looking at Table 7. This has already taken care of Grissom, White and Chaffee and we can now allow for the survival of See, Bassett and Williams by incorporating the following points:

1. Williams was the original choice for Conrad's crew;

2. See was senior to Young, Conrad and Stafford;

3. Young would now be senior to Stafford (Table 9).

In Table 7 we had to replace Eisele in Schirra's crew by Collins but now it would be more appropriate to make a straight swap of Stafford and Eisele between Schirra's and Young's crews because that would put Stafford under the command of Schirra—his old Gemini 6 commander. Table 9 shows the results. Schmitt has been left in Apollo 17 because his inclusion had nothing to do with pilot seniority and Irwin has remained as Apollo 16 LMP because it would be unreasonable to allow Chaffee two Apollo missions with so many astronauts chasing so few flights.

Astronaut Freeman

Ted Freeman died in 1964—another T-38 accident—so it is hard to say when he would have flown. He was a group 3 astronaut, so he could have flown aboard a late Gemini as pilot but he would have certainly got a place in Apollo by the time of Apollo 13 (which used the first of the group 5 men). In this last extreme case it could well have been a Lovell-Freeman-Haise crew. However, he does seem to have been well regarded by his fellow astronauts so he could have flown in an early Apollo by displacing Eisele, Cunningham,

Table 7. Crew composition with successful Apollo 1.

Apollo 1		Grissom	White	Chaffee	Test CSM, Earth orbit
Apollo 2	(8)	Borman	Gordon	Anders	Circumlunar, Block II
Apollo 3	(9)	McDivitt	Scott	Schweickart	LM Earth orbit
Apollo 4	(10)	Schirra	Collins	Cunningham	LM lunar orbit
Apollo 5	(11)	Conrad	Lovell	Bean	First on Moon
Apollo 6	(12)	Stafford	Young	Cernan	
Apollo 7	(13)	Armstrong	Eisele	Aldrin	
Apollo 8	(14)	Shepard	Haise	Mitchell	
Apollo 9	(15)	White	Mattingly	Chaffee	
Apollo 10	(16)	Gordon	Roosa	Irwin	
Apollo 11	(17)	Scott	Worden	Schmitt	

Rapp (who says she has been with the NASA food development programme "forever") work closely with Dr. Charles T. Bourland and several associates from Technology, Inc., stationed at the centre. They spend a great deal of time in the spacious, ultra-modern test kitchen, testing, retesting, then testing again, to be sure that a long list of foods remains fresh and tasty under all sorts of circumstances. They test and taste purchased brand-name foods for quality and stability under widely varying storage conditions and they cook, process and package food for the space missions.

The result of the new system has been a significant lowering of costs, coupled with improved systems. As plans stand now, the older tested systems will prevail during the first several orbiter flight tests.

When operational flights begin, it is expected that the new procedures will be installed and in good working order.

From the beginning of the national space effort, the down-to-Earth topic of food in space has captured the attention of both observers and participants. In the early days, when space flights were short, food was not too important, but it became a more serious consideration, then a vital one, as space travellers began to range farther and stay longer. At first, menus included only the tubes of pastelike food served at room temperature, lukewarm, dehydrated cubes, or a few freeze-dried items. They were consumed without enthusiasm.

Apollo Improvements

By the time the long-duration Apollo flights came into being, the forms and preparation of space food had become more sophisticated, and new heating and cooling methods brought improved palatability.

A breakthrough came during Apollo 8 when the crew was surprised with a home-cooked Christmas dinner – pieces of turkey with most of the trimmings, which was eaten with a spoon rather than squeezed from a container.

The turkey and gravy was a thermostabilized product packaged in a laminated foil pouch. This led to the development of a "spoon-bowl" plastic pack for rehydratable foods into which water was injected through a valve. Contents were spooned out through a zippered opening.

During early Apollo missions, the pattern became standardised: 2,800 calories a day consisting of 16 to 17 per cent protein, 30 to 32 per cent fat and 50 to 54 per cent carbohydrate. Food was of two types: dehydrated cubes and lightweight freeze-dehydrated servings. The cubed foods consisted of solids processed in the form of compressed and/or dehydrated cubes which could be rehydrated by the saliva in the mouth as food was chewed. Freeze-dried foods, which retain flavour, nutrition and fresh appearance even after processing, were reconstituted by injection of a specific amount of hot or cold water. All were packed in heavy plastic.

Skylab Food

Occupants of Skylab fared even better during the three manned missions to the space station. They were given a greater variety of foods at the rate of 1.9 kg (4.4 lb) per day per man, a volume previously unknown in manned space flight. Freezers, refrigerators and warming trays were used for the first time in space. Except for beverages, consumed from a collapsible dispenser, meals were packaged in aluminium cans with the now-familiar pull-off lids.

At mealtimes, the astronauts assembled the cans onto a food warmer-retainer tray from which they dined.

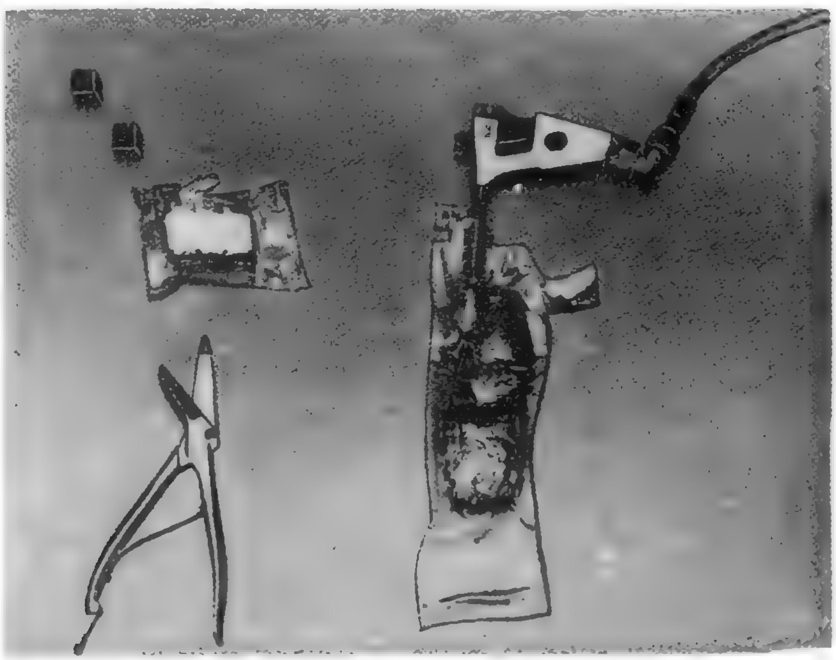
Apollo Soyuz Test Project

American astronauts on the Apollo Soyuz Test Project in 1975 were provided meals similar to Apollo. Russian meals were composed of ethnic foods packed in tin cans and aluminium tubes. A small heater was aboard their spacecraft. Menus were prepared according to each cosmonaut's order and generally consisted of meat or meat paste, bread, cheese, soup, dried fruit and nuts, coffee and cake.

Shuttle

The main differences between Space Shuttle food and that served on earlier flights are:

- *Greater variety and larger amounts.* Seventy-four kinds of food and 20 beverages will be available; caloric content has been increased from 2,800 calories on Skylab to 3,000 on Shuttle because tests have shown that working astronauts need the same caloric intake as ground-based people.



FOOD PACK FOR APOLLO. The water gun injector for space-food reconstitution is shown being used. Scissors are used to cut open the plastic containers.
NASA

- *More efficient handling of food.* A real oven will be in operation in the galley. (Perhaps a refrigerator later if space and power supply permit.) Skylab meals, which were heated by conduction, often were not really hot because of technical problems encountered when correct temperatures could not be maintained because of the low pressure inside Skylab.

  The Shuttle oven, operating in a cabin maintained at standard sea-level atmospheric pressure, can heat meals to 85°C (185°F) and hold levels at 65°C (150°F), and it can heat food in containers constructed from different materials and of different sizes and shapes. Rehydratable foods will be reconstituted by water inserted through a narrow tube that perforates the plastic container rather than the complex valve used earlier. The new food-warmer/retainer trays will be more streamlined, easier to eat from and maintain heat efficiently for hot foods while not affecting temperature of cold items.

  It should be comparatively easy for a crew member to assemble a meal for four in about five minutes, to be heated and ready to eat in about an hour. Clean-up is simple – "wet wipes," containing a cleaning compound are used on trays and utensils.

- *More comfortable, natural dining surroundings.* The comparatively roomy Shuttle galley has a pantry, an oven, a unit for washing up, hot and cold running water, and a dining table.

SPACE RATIONS. Food packs taken into orbit by the Soyuz 31 cosmonauts. Items (top to bottom) are: soups, main course, juices, coffee, bread, confections.

Panorama DDR/Zentralbild

Acknowledgements

The editor would like to thank Ann Weeks, NASA Headquarters, Washington, D.C., and Terry White, Johnson Space Center, Houston, Texas, for information used in this report.

ASTRONOMICAL NOTEBOOK

By J. S. Griffith*

COMETS

A model for the dust release and dust mantle development of comets is presented and qualitative agreement with the behaviour of comet P/Halley obtained.

The occasional irregular outbursts of cometary brightness are superimposed either on a monotonic increase of brightness as the comet approaches perihelion (and decrease as it recedes) or on a brightness asymmetry about perihelion.

Comets that become fainter after perihelion than at a corresponding heliocentric distance before perihelion have been modelled by a cometary nucleus consisting of a growing mantle of evacuated nonvolatile dust surrounding a uniform core mixture of volatile ices and dust. While a fraction of the dust released by sublimation of the surrounding ices is blown away, the rest piles up as loose rubble, providing a growing amount of insulation. This leads to the comet being fainter after perihelion than before.

How can comets that become *brighter* after perihelion be explained? Comet Halley (in 1910) showed such behaviour, and in ref. [1] is modelled, where the dust is totally blown off. Such comets, without any rubble on their surface, are termed 'bald'.

To provide further information, it is recommended that homogeneous sets of observations of monochromatic brightness variations with heliocentric distance be obtained from comets and in particular from the next apparition of comet P/Halley in 1986.

[1] Brin, G.D. and Mendis, D.A., 'Dust release and mantle development in comets', *Astrophys J.*, **229**, 402-408, (1979).

STARS

Does the Sun have a magnetic core?

New solar-type stars may form a dynamically stable toroidal magnetic field in their differentially rotating, stably stratified cores. The significance of such a magnetic core is discussed.

Solar-type stars are thought to form by the rapid accretion of imploding hot gas at their surfaces during the free-fall collapse in the proto-star stage. In ref. [1] it is pointed out that this gives rise to a radiative core with stable differential rotation, and any trapped magnetic field would consequently generate an increasingly stronger toroidal magnetic field by differential winding, with a final magnetic field of around 10^8 gauss arising when uniform rotation is brought about by

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conversion of excess rotational energy into magnetic energy. The author of ref. [1] considers the stability of this strong toroidal magnetic field and finds that certain stars with axisymmetric magnetic fields are stable. A sufficiently strong toroidal field in the core can provide adequate mixing of a star's interior to account for the three classes of old stars which seem to have spent too long on the main sequence: old-disk hydrogen-deficient carbon stars; Type 1 supernovae, and the "blue stragglers" found in globular clusters.

It is also noted that thorough mixing of the solar interior could explain the anomalously low flux of energetic solar neutrinos, and that a magnetic core with maximum field strength 10^8 gauss and magnetic axis at 86^0 to the rotation axis may also account for the 12.2 day solar distortion period.

Internal losses that dissipate the kinetic energy of rotation without loss of angular momentum induce a precession of the toroidal magnetic axis perpendicular to the axis of rotation, maximising the moment of inertia about the rotation axis.

[1] Dicke, R.H., 'Do solar-type stars have magnetic cores? question of stability', *Astrophys J.*, **228**, 898-902 (1979).

Soft X-rays from Vega and η Bootis

Two nearby stars were detected in the soft X-ray band using an imaging X-ray telescope flown aboard two sounding rockets. For Vega it is possible that magnetic field activity may be responsible for heating the corona, and such an explanation may also be true for the second observation. If the unseen companion of η Bootis is degenerate, the X-ray emission may originate in a stellar wind accreting upon a white dwarf or neutron star.

The instrumentation is described in ref. [1] and was flown aboard Aerobee 350 and boosting Black Brandt rockets from the White Sands Missile Range. The detected X-ray luminosities are much closer to that of the Sun than to typical galactic X-ray sources, so an attempt is made to account for the observations in terms of processes analogous to solar coronal activity. Vega is the first solitary main sequence star, apart from the Sun, to be detected as an X-ray emitter. It is now considered that the solar coronal plasma is not solely heated by shock waves in tenuous outer atmospheres (43f. [2]) and that the coronal magnetic field plays an integral part in the energy balance of the coronal plasma. Vega is known to have a magnetic field of the order of 30 times that of the Sun. For η Bootis its spectral type leads to expectation of vigorous convective activity in the outer envelope and a corona hotter and more intense than the Sun's. However, this star is also a spectroscopic binary, and X- rays may originate in accreting material onto the unseen companion. Detection of variability of X-ray emission either synchronised with stellar rotation or orbital motion would be a distinguishing feature.

[1] Topke, K., Fabricant, D., Harnden, F.R., Jr., Gorenstein, P. and Rosner, R., 'Detection of soft X-rays from α Lyrae and η Bootis with an imaging X-ray telescope', *Astrophys J.*, **229**, 661-668 (1979).

[2] Wentzel, D.G., *Rev. Geophys. Space Sci.*, **16**,757 (1978).

X-ray radiation

Images of two supernova remnants, recorded with a rocket-borne imagtng X-ray telescope are discussed. It appears that most supernova remnants result from blast waves propagating into a substantially inhomogeneous interstellar medium, and that caution should be used in modelling them by spherically-symmetric models.

Calculations of X-ray emission from nonmagnetic degenerate dwarfs provide criteria for distinguishing between neutron star and degenerate dwarf X-ray sources.

Using observations from an Astrobee F sounding rocket carrying the imaging X-ray telescope system described in ref. [1] the authors of ref. [2] obtained X-ray images of the Puppis A and IC 443 supernova remnants. Using these observations and those of the Cygnus Loop, Puppis A and IC 443 given in ref. [1], it was found that the X-ray images do not appear as perfect circularly symmetric limb-brightened shells. There is little correlation between the X-ray, optical and radio emission. While not well correlated, the spatial distribution of the three types of emission is confined to a common volume of space, presumably indicating the extent of a propagating blast wave. The lack of circular symmetry indicates an interstellar medium inhomogeneous on large scales. Inhomogeneities of the size of one parsec or less presumably lead to the filaments and knots visible in the optical and radio brightness distributions, while inhomogeneities larger than about ten parsecs appear to dominate the X-ray brightness distributions.

X-ray radiation from degenerate stars is produced by the impact of accreting matter with the stellar surface. The nature of the resulting X-ray and UV spectrum is related to the characteristics of the underlying star and the extreme conditions of temperature and magnetic field strength in the emission region. Observations have not previously been supported by sustematic theoretical studies. Such studies are reported in ref.[3] where it is found that stars undergoing spherical accretion can produce a maximum hard X-ray luminosity of 4×10^{36} ergs^{-1}. Even high-mass stars can produce low-temperature X-ray spectra. High energy tails can be produced by high-mass dwarfs as well as by neutron stars, but for dwarfs there is a pronounced correlation between X-ray spectral temperature and luminosity. All spectra have an intense UV or soft X-ray component, a situation that is not expected for neutron stars. In addition, from the X-ray spectra it should be possible to determine the mass, intrinsic luminosity and distances of those sources which are degenerate dwarfs.

[1] Rappaport, S., Petre, R., Kayat, M., Evans, K., Smith, G., and Levine, E., *Astrophys. J.*, **227**, 285 (1979).

[2] Levine, A., Petre, R., Rappaport, S., Smith, G.C., Evan, K.D. and Rolf, D., 'X-ray images of Puppis A and IC 443', *Astrophys. J.*, Letters, **228**, L99-L104 (1979).

[3] Kylafis, N.D. and Lamb, D.Q., 'X-ray and UV radiation from accreting nonmagnetic degenerate dwarfs', *Astrophys. J.*, Letters, **228**, L105-L110 (1979).

Condensations in the Orion Nebula

The Orion Nebula continues to present new information. Observations using the Lallemand electronic camera located at the Pic-du-Midi Observatory of the core of the Orion Nebula show the presence of condensations, which are explained as Dyson spheres.

The narrow-band observations discussed in ref. [1] were obtained using S 11 and S 20 photocathodes. Six condensations, bright in H_α, H_β and [0 III] but not in [N II] or [S II], were detected, with diameters of the order of the stellar images. These condensations resemble neither Bok globules nor Herbig-Haro objects,

The spheres are about 1.3×10^{15} cms in diameter and dense. They are only partly ionized and are explained as the product of an ionization front penetrating partially inside a neutral sphere. The sizes of the neutral globule and the ionized shell agree well with the predictions of Dyson (ref. [2]).

[1] Laques, P. et Vidal, J.L., 'Detection de condensations d'un type nouveau dans le centre de la nebuleuse d'Orion, au moyen de cellules S 20 associees a la camera electronique Lallemand', *Astron. and Astrophys.*, 73, 97-106 (1979).
[2] Dyson, J.E., *Astrophys. and Space Sci.*, 1, 388 (1968).

The nucleus of our Galaxy

A core-halo model is proposed to account for the reported radio and infrared observations of the Galactic core (Sgr A West), whose dynamical structure can be explained by Keplerian rotation due to the gravitational field of the normal stellar population enhanced by a central mass point of 5 x 10^6 solar masses.

Using previous observations together with those obtained when a single spectral bandpass became possible with the new digital autocorrelator on-line at the Haystack Observatory, the authors of ref. [1] constructed a core-halo model of Sgr A West. Emission from the core dominates the infrared lines, while that from the halo dominates the radio lines. From the rotational velocities inferred from spectral line widths, the presence of a central mass of 5 million solar masses was deduced. It is noted that in ref. [2] a supermassive nonstellar object is proposed in the core of M87, about a thousand times more massive than the one required to explain the dynamics of the ionized gas in the nucleus of our Galaxy.

[1] Rodriquez, L.F. and Chaisson, E.J., 'The Temperature and dynamics of the ionized gas in the nucleus of our Galaxy', *Astrophys. J.*, **228**, 734-739 (1979).
[2] Sargent, W.L.W., *et al*, *Astrophys. J.*, **221**, 731 (1978).

QUASARS

Alignment of quasars?

Eight quasars were found in a linear formation across the galaxy NGC 1073.

Using the 5 m Hale telescope at Palomar the authors of ref. [1] investigated known quasars near the triple galaxy system NGC 3379/84/89 and discovered others. A total of eight quasars appear to be aligned across NGC 3384. The quasars closest to NGC 3384 pair exactly across the centre of the galaxy with close redshifts. The next outermost pair is also well aligned across the centre but at 5° to the first pair.

It is pointed out that NGC 3379 is the brightest galaxy in the region investigated with NGC 3384 being symmetrical, somewhat smaller and having the appearance of a moderately tilted SO galaxy. Its nucleus has an unusually high surface brightness nucleus. It is considered that this investigation shows that at least some quasars can be demonstrated unequivocally to be associated with some low redshift galaxies. It appears that the quasars were ejected in pairs as are radio sources.

In ref. [2] three quasars in the spiral arms of the galaxy NGC 1073 are reported. After surveying the Palomar Sky Survey prints, use of the 1.2m Palomar Schmidt confirmed the existence of three stellar objects situated on the edge of NGC 1073 with an ultraviolet excess. Spectra of them were then obtained with the Hale 5m telescope, and after some further observations their nature as quasars was revealed. They are situated in or near the edge of the galaxy but their redshifts range from $z = 0.6$ to $z = 1.9$. However, it is estimated that the probability of chance occurrence is about one in a thousand.

[1] Arp, H., Sulentic, J.W. and Tullio, G. di., 'Quasars aligned across NGC 3384', *Astrophys. J.*; **229**, 489-495 (1979).
[2] Arp, H. and Sulentic, J.W., 'Three quasars near the spiral arms of NGC 1073', *Astrophys. J.*, **229**, 496-502 (1979).

Deuterium production

The amount of deuterium produced in the 'big bang' is very sensitive to primaeval conditions (in particular the baryon density). It is therefore of great interest to discover whether there is any astrophysical process that can produce deuterium. It is found that any such process would produce a greater high-energy neutrino flux than is detected.

In ref. [1] it is pointed out that it appears only possible to produce deuterium by neutron capture or by the shattering of a nucleus that is heavier than deuterium.

Neutron capture seems to demand processing through an explosion like the big-bang, while shattering could be produced by spallation models only if 1% of the rest energy of all matter is spent on deuterium production. Such vast energy sources are quasars and/or active galactic nuclei, but in ref. [1] it is pointed out that high-energy neutrinos are the chief decay product of the nuclear collisions, and they are not observed, unless the sources are at very high redshifts ($z > 300$).

The neutrino emission could be suppressed if the ambient density at the site of deuterium production is greater than 10^{20} cm^{-3}, but then it is expected that the deuterium would be burned up to heavier nuclei.

[1] Eichler, D., 'The high-energy neutrino background: limitations on models of deuterium production', *Astrophys. J.*, **229**, 39-41 (1979).

TELESCOPES

Silica fibre link between telescope and spectrograph

An experimental fibre link of 20m length between the prime focus and a spectrograph located in a laboratory below was tested using a TV guiding system to hold star images on the fibre entrance. The system was compared with spectra obtained with the same telescope but with the spectrograph mounted at the Cassegrain focus. These tests demonstrate the practicability of the FLOAT 500m² aperture optical telescope.

The Fiber Linked Optical Array Telescope (FLOAT) was proposed by Angel and his co-workers (ref. [1] and [2]. Essentially it involves multiple mirrors with separate foci and separate instrumentation. If desired fused silica communications fibers may be used to link the mirrors to a single system. As a test it was decided to mount a fiber at the prime focus of a telescope to try out the idea. The results of the experiment are described in ref. [3], and the telescope used was the Steward 36 in. (91 cm.) telescope.

Light diverging away from the focal plane is refocused into a guiding television camera without blocking the field immediately surrounding the fibre. Several objects down to 15th magnitude were observed, and the nucleus of NGC 4151 with the fibre optics and with the same spectrograph in Cassegrain configuration are given. The conclusion is that using optical fibres as long as 20m for the transmission of light from a telescope to an instrument is practical. The losses of the fibre link at most wavelengths are less than at any normal codé focus and there is no need to maintain mirrors at high reflectivity.

[1] Angel, J.R.P. in 'Optical Telescopes of the future' (Geneva: ESO C/o CERN) p. 227 (1978).
[2] Angel, J.R.P., Adams, M.T., Boroson, T.A. and Moore, R.L., *Astrophys. Jr.*, **218**, 776 (1977).
[3] Hubbard, E.N., Angel, J.R.P. and Gresham, M.S., 'Operation of a long fused silica fiber as a link between telescope and spectrograph', *Astrophys. J.*, **229**, 1074-1078 (1979).

APPROACHING THE PAD. The move proceeded smoothly and was successfully concluded at 7.20 p.m. when the Mobile Launcher Platform was hard-down on its mounts on the pad.

NASA

you die. That's the chance you take when you're a test pilot."

Following the celebrations sponsored by the National Space Institute in Las Vegas, Nevada a group of 600 persons including 150 astronauts and their families were entertained by former President Richard M. Nixon. In attendance were Al Worden, Walt Cunningham, Buzz Aldrin, Bill Anders, Ron Evans, Dick Gordon, Curt Michel, Jim Irwin, Jim Lovell, John Swigert, Stuart Roosa, and Charles Duke. The widows of astronauts Williams, See, Givens, and White were also in attendance.

The public questioning of the safety of the Space Transportation System brought a quick rebuttal from NASA and in the person of astronaut Bob Overmeyer, the deputy manager of Orbiter manufacturing. Overmeyer commented "The astronaut office feels very strongly that we are building a safe vehicle.... We are not going to sacrifice quality, reliability and safety."

The NASA vehicle manager at the Kennedy Space Center's Orbiter Processing Facility Ken Kleinknecht: "All I can say is they know how to get headlines and maybe that's why they are no longer in the programme.

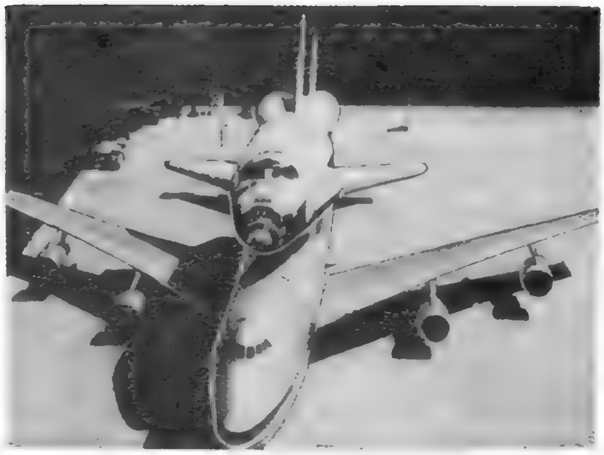
"I'll tell you one thing. I have never and will never allow myself to be compromised in safety, quality or reliability in order to keep a schedule."

He elaborated on the Shuttle preparations and schedule: "It will be a challenge to reach a March 1980 launch, but we will try as hard as we can to make that date.

"Testing is both ahead and behind schedule."

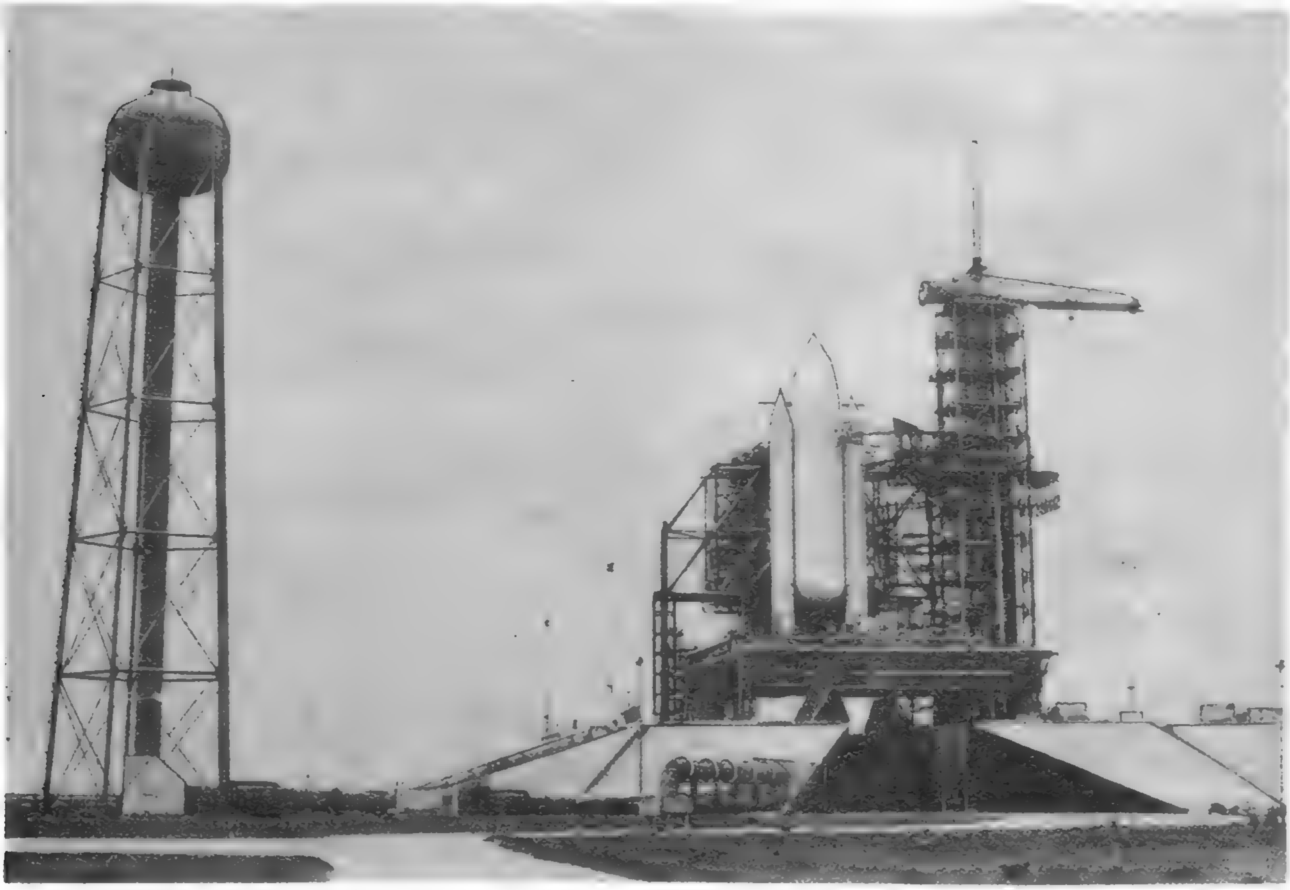
Installation, according to Kleinknecht, of the thermal protection system tiles is proceeding at a good pace with some 478 tiles having been installed during the second week of July.

"But we do have a problem with some 600 to 1,500 additional tiles that might have to be removed because they may not be strong enough."



'COLUMBIA' ARRIVES. After being ferried 2,400 miles (3,860 km) from the Dryden Flight Research Center in California, the Orbiter 'Columbia' arrives at KSC aboard the 747 mother for final assembly and preparation for flight.

NASA



DRESS REHEARSAL. In the meantime, the Shuttle that will not fly into orbit undergoes a series of checks on Launch Complex 39A. Solid Rocket Boosters and External Tank closest to camera, Orbiter on far side enclosed by Rotating Service Structure.

Stephen Smyth

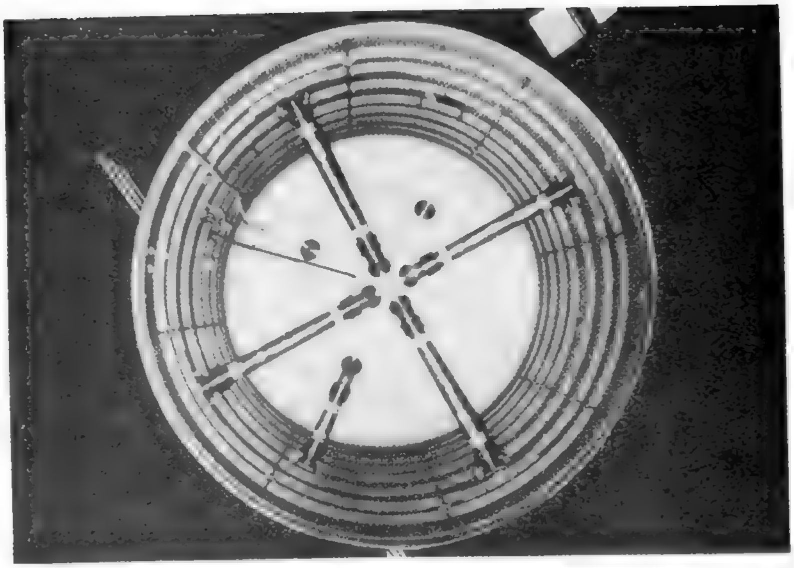
British contributions to Ariane.

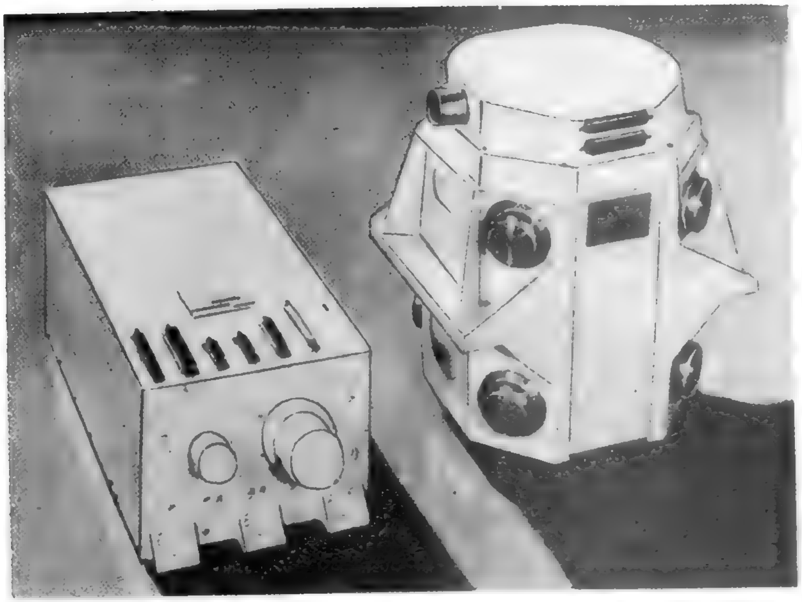
Right, Ferranti inertial measuring system comprises two units, the inertial platform (right) and the electronics unit (left).

Ferranti Limited

Below, propellant ducts leading from the upper N_2O_4 tanks of Ariane's first stage. Each duct incorporates an Avica all-stainless-steel sliding joint at its inboard end and a gimbal joint at its inboard end – all bellows-sealed. The company's bellows-sealed flexible joints appear on all stages of the launcher (see also *Spaceflight,* August-September 1979, page 379).

Avica



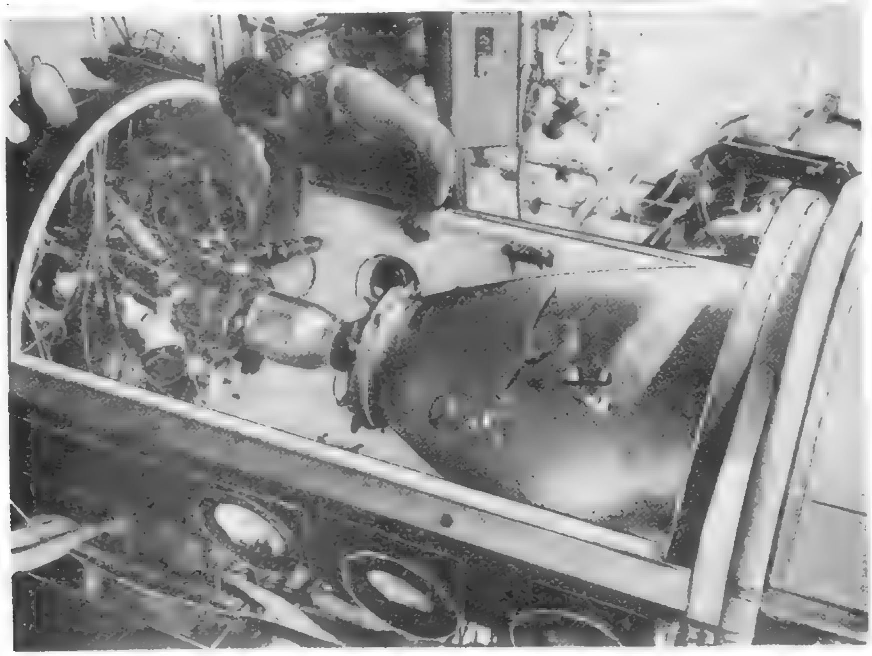


Above right, France and West Germany combined to build the LO_2/LH_2 HM7 rocket engine for the third stage.

SEP

Right, HM7 thrust chamber developed and manufactured by Messerschmitt-Bölkow-Blohm under contract to CNES/SEP.

M-B-B



NEW LIGHT ON VENUS

Interim findings from the 1978 Pioneer Venus Orbiter and Multiprobe missions include:

- A 15,000 ft (4920 m) deep, 900-mile (1448 km) long rift valley, the largest canyon yet found in the Solar System.
- Confirmation of what appear to be periods of virtually continuous lightning in the atmosphere and of a continuous strange glow at night near Venus' surface.
- Evidence for a 650-mile (1046 km) wide, roughly-circular region of down-flowing winds over the poles, perhaps a key mechanism in Venus' global atmosphere circulation.
- Dramatic new pictures of the planet.
- Unique, perhaps planet-spanning, "magnetic rope" structures in Venus' ionosphere.

Venus' newly-found rift valley is three miles (4.8 km) deep and 175 miles (280 km) wide. Pioneer radar mapper measurements found the canyon to be at least 900 miles long with no apparent beginning or end. This geologic feature is deeper than anything on Earth and appears larger than *Valles Marineris* on Mars, previously the Solar System's largest canyon.

The Soviet Venera 11 and 12 probes found continuous lightning activity from 19.8 miles (32 km) down to about 1.2 miles (2 km) altitude, with discharges as frequent as an incredible 25 per second. The Pioneer Orbiter also observed this lightning, measuring such discharges during every pass across the planet's night hemisphere.

The eye would not be able to separate such frequent flashes and an observer on Venus might see the landscape and dense atmosphere bathed in a continuous, eerie electrical glow, accompanied by continuous peals of thunder.

Pioneer experimenters, Dr. Boris Ragent, Ames Research Center, and Dr. Jacques Blamont, University of Paris, now believe that the "mysterious glow" measured by their instruments is real light on Venus, and not something happening on the spacecraft. The glow started at about 10 miles (16 km) altitude, and increased as the two night-side probes approached the surface.

"Chemical fires" due to reactions of various compounds in the super-heated atmosphere close to, or on, Venus' surface have been cited as a possible source for the glow. Pioneer measurements suggest a "chemical brew" near the surface whose reactions could fuel such "fires."

Lightning discharges also are a possible source of this glow, except that the increasing intensity observed going down would be unlikely for lightning, as would be the very steady character of the glow.

The Pioneer Orbiter's infrared radiometer has found both a depression in the clouds at the north pole, and an actual 682 mile (1100 km) wide hole where there were few or no clouds. This finding strongly suggests a downflow of atmosphere at the pole. There also is evidence for such planet-wide atmosphere flow in temperature measurements made by the Pioneer Sounder Probe at the equator and the North Probe at 60° north latitude. New probe findings also show that before the clouds Venus atmosphere is remarkably uniform in temperature and pressure at all latitudes and in both day and night hemispheres.

The new Venus pictures provide a sequence showing global cloud movements. They show, among other things, that Venus' planet-spinning C- and Y-shaped dark markings result from dark clouds (probably sulphur) below the highest cloud layer.

Venus from Pioneer Venus Orbiter on 19 February 1979 from a distance of 40,600 miles (65 325 km).

NASA

The interplanetary magnetic field appears to be compressed, wrapped around itself, and twisted into unique magnetic ropes within Venus' ionosphere.

Historical Discoveries About Venus

684 BC	Ninevah tablets record observations of Venus.
1610	Using the newly-invented telescope, Galileo finds that Venus exhibits phases like those of the Moon.
1761	Mikhail V. Lomonosov (USSR) interprets optical effects observed during transit of Venus as due to an atmosphere on the planet.
1792	Johann H. Schroter (Germany) concludes Venus has an atmosphere because the cusps at the crescent phase extend beyond the geometrical crescent.
1807	Johann Wurm (Germany) determines the diameter of the visible disc of Venus as 12,293 km (7,639 miles).
1890	Schiaparelli concludes from his observations that Venus rotates in 225 days.
1920	Edward St. John (U.S.) and Seth B. Nicholson (U.S.) suggest that Venus is a dry, dusty world because they cannot detect any water vapour in its atmosphere.
1922	Lyot measures the polarization of sunlight reflected from the clouds of Venus and introduces a new method of investigating the size and nature of particles in its clouds.
1932	Walter S. Adams (U.S.) and Theodore Dunham (U.S.) detect carbon dioxide in the atmosphere of Venus.

1942 Rupert Wildt (U.S.) shows that the high surface temperature of Venus could arise from a greenhouse effect in an atmosphere with a high proportion of carbon dioxide.

1955 Fred Hoyle (United Kingdom) suggests that the Venus clouds are a photochemical hydrocarbon smog.

1956 Radio waves at 3-cm wavelength are detected from Venus and show that the surface temperature is very high; about 330 deg C (526 deg F).

1957 Charles Boyer (France) discovers a four-day rotation period of the ultraviolet markings in the clouds of Venus.

1960 Adouin Dollfus (France) determines pressure at cloud tops as 90 millibars, using polarimetry.

1960 Carl Sagan (U.S.) calculates heating in atmosphere with large amounts of carbon dioxide and water vapour, concludes surface temperature can be raised by greenhouse effect to above the boiling point of water, 100 deg C (212 deg F).

1962 Low radar reflectivity of Venus rules out any possibility of there being large bodies of water on the planet's surface.

1962 Radar observation of Venus establishes rotation as retrograde in a period of approximately 240 days.

1962 Mariner 2 flyby confirms high surface pressure (at least 75 atmospheres) and temperature (about 650 deg K) and shows no substantial magnetic field.

1967 Mariner 5 flyby uses radio occultation to measure structure of upper atmosphere and locate height of clouds above surface; discovers ionosphere and finds that carbon dioxide is major compound of atmosphere.

1967 James Pollack (U.S.) and Sagan calculate greenhouse effect for massive Venus atmosphere, showing that solar energy alone can heat surface to above 450 deg C (845 deg F).

1968 Radius of Venus surface determined from radar to be 6,050 km (3,750 miles) with uncertainty of less than 5 km (3 miles).

1968 Surface temperatures and pressures are estimated from radio and radar data as 477 deg C (890 deg F). and 90 atmospheres.

1969 USSR probes, Venera 5 and 6, successfully land on surface, determine accurate temperature (750 deg K) and pressure (90 atmospheres), also structure of lower atmosphere.

1971 Analysis of polarization data by James Hansen and Albert Arking (U.S.) shows that the cloud particles are spherical with a refractive index of 1.44, radius of 1.05 μm and a location at a pressure level of 50 millibars.

1972 A. T. Young and G. Sill (U.S.) independently conclude that the polarization data imply that Venus clouds are composed of sulphuric acid droplets.

1972 USSR Venera 8 lander measures radioactive content of surface rocks, concludes Venus is differentiated. Also determines that sunlight (a few per cent) penetrates to surface.

1973 Observations of carbon dioxide absorptions in Venus atmosphere show a 20 per cent fluctuation over a four-day period, interpreted as upward and downward motions of cloud deck planetwide.

1973 Radar scans of Venus reveal huge shallow craters on the planet's surface.

1973 Pollack makes observations of Venus from high-flying aircraft and concludes that clouds are deep hazes of sulphuric acid drops.

1974 Richard Goldstein (U.S.) produces high resolution radar images of small areas of the planet's surface showing many topographic features.

1974 Mariner 10 (flyby) obtains detailed ultraviolet photographs of clouds, determined circulation patterns in upper atmosphere.

1976 USSR Venera 9 and 10 landers photograph surface at two locations, showing exposed rocks and evidence of erosion processes.

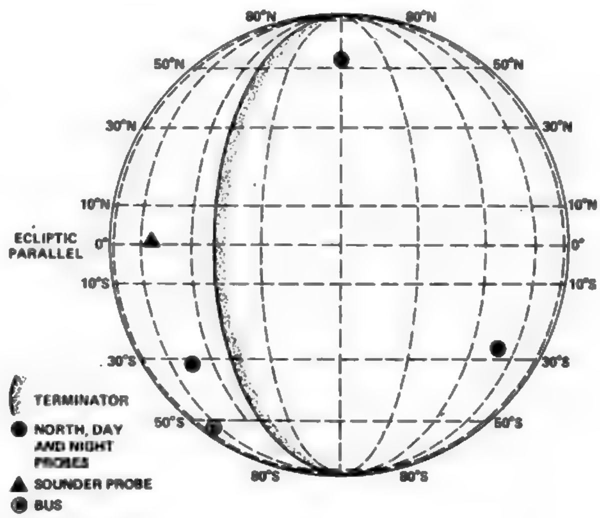
1976 Arvydas Kliore (U.S.) and colleagues conclude from radio occultation data that additional discrete cloud layers exist below the main sulphuric acid clouds.

1977 Radar images with the upgraded Arecibo radar indicate large volcanoes and craters on planet.

1978 Pioneer Venus 1 begins detailed studies of Venus from orbit. Five entry probes of Pioneer Venus 2 find several hundred times more primordial argon and neon on Venus than on Earth.

1978 USSR Venera 11 and 12 on fly-by course release landing capsules. Find ratio of argon 36 and argon 40 to be "200 to 300 times greater" than on Earth.

VIEW FROM EARTH OF PROBE ENTRY LOCATIONS



Pioneer Venus 2

NASA

SKYLAB – THE LAST HOURS

The Skylab space station finally reentered on 11 July 1979 and, just as it had done during its six year life, contradicted the predictions of NASA, writes Andrew Wilson. The final target area was in the southern Indian Ocean but reports from Australia proved that some debris had reached that far.

Launched in May 1973, Skylab was built in the S-IVB second stage of a Saturn IB and occupied by nine astronauts for a total of 172 days up to February 1974 when it was abandoned to its fate. The last crew did, however, raise the orbit of the station with their Apollo spacecraft engine. Studies of the Sun with the Apollo Telescope Mount have lead to a better understanding of solar mechanisms but it is ironic that our poor knowledge of the Sun lead to Skylab's early downfall. NASA quoted a decay state of 1983, when the Space Shuttle would have been available to guide it down to a safe landing.

However, NASA appears to have made quite an error because our own RAE (Royal Aircraft Establishment) made its first prediction after the last astronauts had left, it arrived at 6 years ± 7 months, making the most likely descent date as May 1979. The RAE took more notice of the expected increase in upper atmosphere densities as the radiation output of the Sun approached maximum. NASA woke up to the dangers and in July 1978 it manoeuvred Skylab into a low-drag position with the hope of keeping it in orbit until the Shuttle could fly a rescue mission. An astronaut trained in simulators with the TRS (Teleoperator Retrieval System) which would have been able to either boost Skylab into a safe orbit or drop it into an ocean but NASA announced on 12 December 1978 that the plan was cancelled. The rapid decay of Skylab and the slippage in Shuttle launch dates made it unworkable.

Two studies were conducted for rescue missions using expendable boosters but they were dropped through lack of time and it was even suggested the Russians could come to the rescue with Soyuz. However, that vehicle was below the capabilities needed for such a mission.

The July attitude change reduced drag by 2½ times and the RAE gave a prediction of November 1979 for the descent but on 25 January 1979 NASA commanded the station into a new solar inertial position. This was designed to provide power for a controlled re-entry but it meant drag was increased and so the RAE brought its prediction forward to July 1979.

On 2 April, the RAE predicted 30 June ± 15 days. The large error indicates why no impact location could be given – to be able to do that required pinpointing atmospheric re-entry to within a *few seconds*. On 8 May, 5 July ± 10 days was given and at about this time the first glimmerings of interest from the media appeared. As re-entry came closer, the predictions became more specific: 4 June-8 July ± 5; 2 July-12 July ± 1. Between these two dates two more manoeuvres had been made.

Early July saw feature writers of the press dust off their Skylab manuals to illustrate the forthcoming dangers; pressure vessels of titanium and steel (oxygen tanks of 2700 lb (1230 kg) were the largest), a 4000 lb (1820 kg) film safe and the 5000 lb (2280 kg) airlock shroud were the most likely candidates for survival from the 157,000 lb (71,400 kg) space station. At this stage, the impact location was still unknown but NASA was quoting odds of 1 in 152 of a single injury from debris and reminding people that on average nine man-made space objects re-enter every month. In the event of any damage, the Convention of International Liability which came into force in 1976 would require, under Article II, the Americans to pay full compensation.

If, on the last day of the flight, areas like Europe and Asia had been in the major danger zones re-entry could have

ARTIFICIAL METEORITES. Fragments of Skylab are examined at MSFC be members of the Center's Skylab reconnaissance team which brought pieces back from Australia. The team's mission 'down under' was to learn more about the dimensions of the Skylab 'footprint' as the space station re-entered the atmosphere, and the condition and precise location of the debris. The group interviewed eye-witnesses of the re-entry spectacle and people who found the remains. Small samples of various materials were collected for analysis to see what effects long-term exposure (more than six years) in space had had on them. *Left to right*, Billy Adair, electronics equipment and trajectory specialist; J. M. Jones, public affairs officer; Dr. Ray Gause, materials specialist; and William (Ozzie) Harrison, structures specialist.

NASA

CHARCOAL FRAGMENTS. These small charcoal fragments were brought to the United States by 17-year old Australian Stanley Thornton, who picked them up from his yard in Esperance after Skylab re-entered. The *San Francisco Examiner* had offered to pay $10,000 for the first recovered Skylab debris.

NASA

been delayed by almost four hours – equivalent to three revolutions – effectively shifting the impact area by several thousand miles. Finer control was considered during the very final stages by firing the attitude control thrusters with every minute of delay moving the target area by some 300 miles.

The RAE estimates were gradually brought forward (July 12.1, July 11.9, July 11.7, and July 11.6) as a result of increased solar activity and on the day before re-entry decay was predicted at 1400 GMT ± 3 hours if no further attitude changes were made.

Twelve hours before expected impact, NORAD predictions indicated that Canada and Maine were in danger and the decision was made to take evasive action.

By this time, Skylab was travelling side-on in a high-drag attitude so at 0245 Houston time (0745 BST) the command was sent up to begin a tumble in order to reduce drag and extend the lifetime by half an hour. Altitude was down to 80 miles (130 km) and re-entry over the North Atlantic with impact in the South Atlantic or southern Indian Ocean was hoped for in Houston and Washington. A PA man in Houston was confident enough to say "We have absolute control over Skylab!" Disintegration at 58 miles (93 km) was expected.

As the day wore on, splashdown into the Indian Ocean after re-entry at 1730 BST became most likely with limits of 1701 to 1753 BST. At 1700 BST, Skylab had cleared the North American continent and was travelling south over the Atlantic, leaving Australia as the only major land mass in danger. The station was still tumbling rapidly.

Final telemetry received at the Ascension Island tracking station showed the solar panels were twisted back and by 1730 BST Skylab was out of range, obviously close to breaking up. A pilot on an internal Australian flight at 27,000 ft, 120 miles (192 km) east of Perth saw a bright blue light as Skylab streaked across the sky with the colour turning to orange as break up began. Most of the debris appears to have fallen into the Indian Ocean but glowing fragments were seen crossing the Australian coast at Esperance and travelling over Balladonia, 100 miles (161 km) inland. Very loud sonic booms over a period of two minutes were reported by people on the ground. Skylab had completed its 34,981st – and its last – orbit.

The world awaited to see if any injury or damage had been caused but it soon became apparent that none had and the main interest centred on the hunt for remains in the Australian outback. Up to 1000 people began searching but the biggest piece appears to have been a 6 ft long, 3 ft diameter, half ton cylinder found near Rawlinna, 550 miles (880 km) east of Perth. The winner of the race to claim the $10,000 offered by the San Francisco *Examiner* newspaper for the first pieces of Skylab to arrive at its office was a 17-year old lorry driver from Esperance, a town 450 miles (720 km) from Perth.

The writer would like to thank Doreen Walker, who made the RAE predictions, and Desmond King-Hele for their help.

GENERAL STAFFORD ON SPACE

Former astronaut Thomas P. Stafford and now Deputy Chief of Staff for Research and Development at the Pentagon for the U.S. Air Force* recently addressed the Annual Reunion Banquet of the Missile, Space and Range Pioneers. The topic of Lt. Gen. Stafford's address was "The US/USSR Space Programmes."

Stafford in his opening remarks to a banquet hall filled with such space programme notables as Walter J. Kapryah and Lee Scherer, recalled his role in the Gemini and Apollo programmes, particularly "those many hours on the pad at night and early in the morning in the firing rooms.

Since arriving at the Pentagon, a place he termed the five-sided Puzzle Palace, Stafford expounded his pride in representing the Air Force's role in the Space Shuttle both as executive agent for the Department of Defense and before four congressional committees. Based on his experience in the preparations for the first flight of the Gemini and Apollo programmes, it takes 50% more time to complete the preparation procedures than under normal operational conditions. "And finally we find at the end that we achieved far more than we ever expected. It worked that way in Gemini and it worked in Apollo and all the rest. And I'm very confident that the Shuttle, once we get it going, which we're going to do, is going to be better than we could even imagine today."

Stafford likened the performance of the Space Shuttle to an epitaph on a tombstone in the British Isles seen by a friend, "Here lies Molly O'Laughlin. She was the soul of virtue in her later years."

Stafford reflected on the state of the national consciousness of the United States as opposed to that of the Soviet Union. Drawing on his experience in dealing with the Russians during the Apollo-Soyuz Test Project he concluded that the Soviet leadership had succeeded in instilling an ongoing sense of national purpose in their people. Stafford deplored the expression "self-doubt and possible trend toward isolationism" afoot in America today.

American faced many problems "in the wake of Vietnam, Watergate, the rise of OPEC, and the fall of the Shah, with the Soviet Union assuming a far more aggresstive stance in the world in respect to its power projections with the position to upset the power structure that we have today."

"In preparations for my fourth mission in Space, Apollo-Soyuz, I had to learn the Russian language and meet the Russian people. When we were here, again before the mission, we had the cosmonauts to a Manned Flight Awareness Symposium in New Orleans with the Chrysler people. It was going to be the last time that we flew that booster, the S-IB. They were told that , after that, all these people would be laid off. That just completely boggled the Soviet's mind. They could not understand how we had these engineers, this great talent, the technicians, that had done all these things so successfully and then lay them off. They could not believe it. If you go to the Soviet Union and see the whole system and a whole generation of ICBM's, you see how they keep them going all the time to keep the team together. You see it whether in ballistic missiles, space, or in the armament of tanks. They keep the teams together."

* *Lt-Gen. Stafford retired from this post on 1 November 1979.*

NASA CALLS FOR GROUP 9 ASTRONAUTS

Between 1 October and 1 December 1979, the National Aeronautics and Space Administration (NASA) will be accepting applications from men and women who want to become Shuttle astronauts in the 1980's, writes David J. Shayler.

Positions for both Pilot and Mission Specialist Candidates are open and NASA is expected to give priority to US citizens although the applications are not confined to the American States. Both Civilian and Military applications will be accepted and following the usual screening successful candidates will report to the Johnson Space Center, Houston, Texas, in mid-1980 for a initial 12 month training period

following which NASA will select candidates from both categories for further training and eventual inclusion into the Shuttle flight crew rota.

Qualifications for the Pilot candidates are similar to those issued three years ago when NASA last put the call out for astronauts for the Shuttle programme. All candidates must have a degree in engineering, mathematics, the physical or biological sciences. In addition they must have accumulated at least 1,000 hr in command of high performance jet aircraft, be passed by a NASA medical examination and stand between 1.63 m and 1.93 m tall.

Similar experience and qualifications apply to the 1979 applicants for Mission Specialist as those in 1976. Degree qualifications are the same for the Pilot applicants but three-years related experience at the minimum is also required, or equally a higher degree in their specialised area of study. Flight experience is not needed but all applicants must again pass the NASA medical and stand between 1.52 m and 1.93 m tall.

The latest group of 35 astronaut selected in January 1978 are well advanced with their two-year training programme, which is due to be completed in July 1980. Successful candidates from these 35 astronauts will then be assigned to Shuttle duties as fully qualified astronauts.

A total of 26 astronauts remain from the first seven groups selected between 1959 and 1969 available for Shuttle flights, 11 of these being scientist astronauts. Seven of these astronauts are entering the final stages of preparations for the Shuttle Orbital Flight Test Programme due to commence next year; two others are training for the first Spacelab mission in 1981.

NOCTILUCENT CLOUDS ANALYZED

Cosmonaut Pyotr Klimuk who commanded Soyuz 13 when it went in orbit on 18 December 1973 said in an interview recently that noctilucent clouds consisted of ice crystals. He was the first to observe and photograph the noctilucent clouds. A spectrogram obtained by the Salyut 4 spacelab was analyzed by Russian scientists enabling them to reach some interesting conclusions, writes Julian Popescu.

"Noctilucent clouds occurred at a very high altitude of the Earth's atmosphere," he said. "The ice crystals condensed on particles of meteoric dust or micrometeorites which penetrated the atmosphere without burning up. The crystals had the unique property of reflecting electromagnetic waves. Weathermen, communications specialists and spacemen were interested in knowing more about these clouds which shone by night and could not be seen from Earth. Subsequent research in the West showed that the crystals in these clouds were shaped like needles, hence their peculiar striped appearance."

STEPPING STONE TO MARS?

For some time now the Russians have been carrying out experiments and tests with both manned and automatic space flight in near-Earth orbits, writes Julian Popescu. But Academician Sagdeyev, Director of the Institute of Space Research in Moscow's Profsoyuznays Ulitsa was quoted by Radio Moscow on 23 July 1979 as saying that the USSR would continue the exploration of the planets.

He referred first to the use of automatic spacecraft for the exploration of the Moon, Venus and Mars. Dealing then with manned space travel, Sagdeyev hinted that the Russians had in mind the creation of permanent skylabs with "interchangeable crews." He envisaged large skylabs with crews of more than four, perhaps ten or even 20 cosmonauts. The skylabs would stay in orbit for up to ten years. The aim was to study the effects of weightlessness on humans, preparatory to a mission to Mars.

UK METSAT SENSOR

Excellent data is being received from the stratospheric and mesopheric sounder (SAMS) aboard one of the latest American weather satellites Nimbus 7. SAMS, for which the British Aerospace Dynamics Group was prime contractor, records variations in infrared radiation throughout the atmosphere on a global basis as Nimbus orbits the Earth approximately 14 times a day.

The advanced radiometer, operating in the IR region, is sampling conditions at altitudes between 30 and 130 km in an experiment devised by Professor J. T. Houghton of Oxford University's Department of Atmospheric Physics. The Science Research Council provided the finance for SAMS and design and development were shared by the University, the SRC's Rutherford Laboratory and BAe Dynamics Group's Stevenage space engineering department.

From the data obtained the quantity, distribution and movement of the selected gases, ranging from carbon dioxide and water vapour to rare constituents such as oxides of nitrogen, can be assessed. Many of the gases are associated with pollution problems.

74°, 95 MIN COSMOS SATELLITES

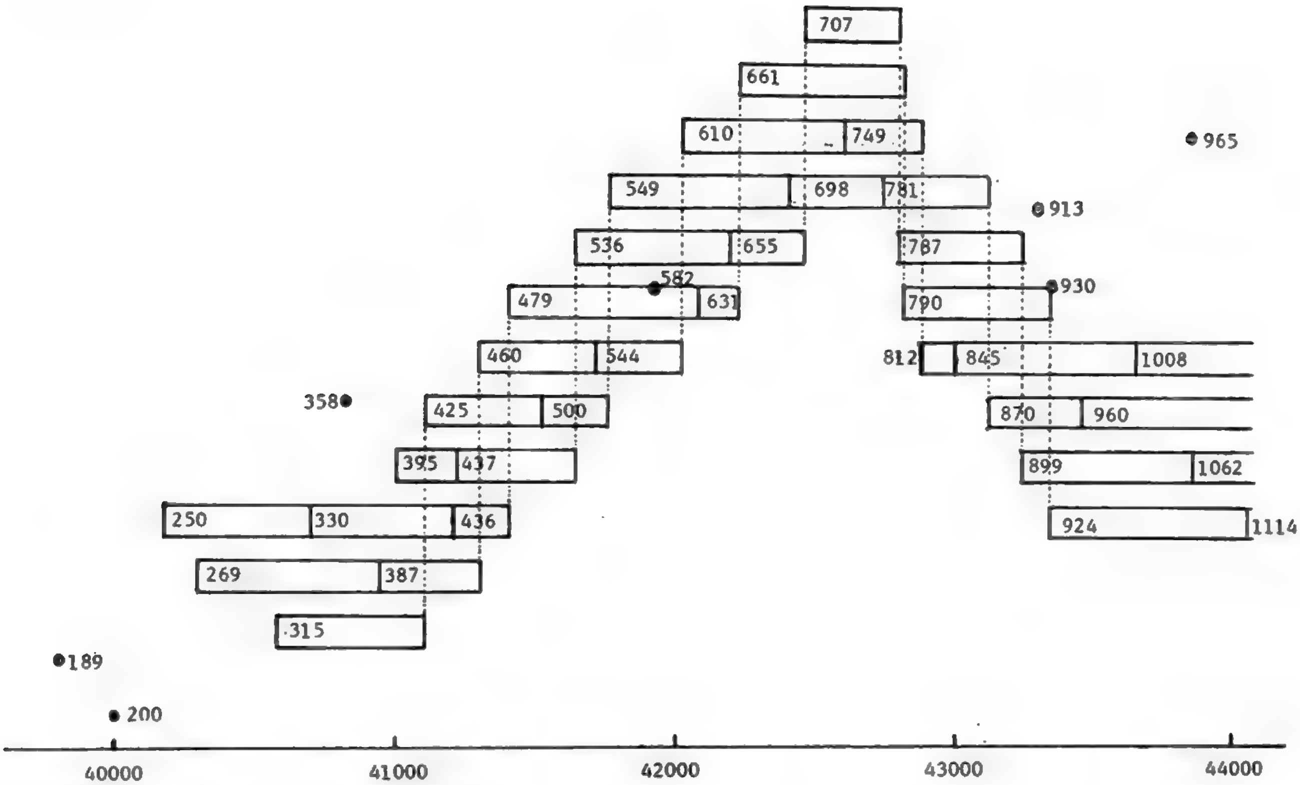
The Soviet Union has been launching Cosmos satellites into near-circular orbits of 95 min period at 74° inclination since 1967. It has been suggested that these satellites perform electronic intelligence gathering (ELINT) or "ferret" missions [1], writes G. E. Perry and Sarah M. Mobbs, of the Kettering Group.

Analysis of the right ascensions of the ascending nodes show that, since 1968, these satellites have been placed at orbital plane spacings of 45° to one another, thereby ensuring global coverage [2]. Figure 1 shows these relative spacings as a plot of right ascension against date. The horizontal bars are spaced 45° apart but no specific values of RA are given since, in such an orbit, RA changes at a rate of -2.07°/day.

When new satellites are placed in the same orbital planes as their predecessors, it is not unreasonable to presume that this occurs near the end of the operational life of the elder satellite and that the new satellite is a direct replacement. Thus, Cosmos 330 replaced Cosmos 250 and was, in turn, replaced by Cosmos 436.

It can be seen that there is another type of replacement in which the new satellite is placed into a plane 180° away from the ailing satellite, such as the replacement of Cosmos 315 by Cosmos 425.

In the first four years, the operational system consisted of four satellites at any one time. The launches of Cosmos 425, 460, 479 and 536 suggested that this was being extended to an operational system of eight satellites [3]. However this implies an operational life in excess of four years for Cosmos 500 and the failure to replace Cosmos 749, 781, 787 and 790 within a period of more than three years now suggests that there has never been more than four operational satellites at any one time and that Cosmos 812 and its early replacement Cosmos 845, and Cosmos 870, 899 and 924 merely provided a transition to planes in the opposite hemisphere. An inclination of 74° is close enough to a polar orbit for four satellites to suffice to give complete global coverage of populated areas by.



Relative spacings of right ascensions of ascending nodes.

utilising both the northbound and southbound passes in each orbit.

This hypothesis gains cradibility from the launches of Cosmos 960, 1008, 1062 and 1114 as direct replacement for Cosmos 870, 845, 899 and 924, and the use of the opposite hemisphere for the obscure missions of Cosmos 913, 930 and 965. Cosmos 930 remained attached to the final stage of its launch vehicle and the other two fragmented in orbit.

The alignments specified as Groups A and B by Clark [4] can be explained as the results of regular campaigns of replacement at intervals of the order of 200 days.

The authors wish to acknowledge the use of NASA two-line orbital elements provided by the Goddard Space Flight Center.

REFERENCES

1. Soviet Space Programs, 1971-75, Vol. 1, U.S. Government Printing Office, 1976, p. 406.
2. *Ibid*, p. 406.
3. *Ibid*, p. 406.
4. Phillip S. Clark, *Spaceflight*, 20, pp. 298-304, (1978).

ESA TO USE PRICE SYSTEM

Arrangements for the European Space Agency (ESA) to use the parametric cost-estimating system, PRICE, in the development and production phases of all its scientific, technical and communications satellites and other space projects, have been made under a contract recently concluded with Atkins On-Line, the leading UK timesharing bureau. The contract was signed with ESTEC, the technical centre of ESA, through the company's office in the Hague.

PRICE will also be used as a tool to assist in the evaluation of bids made by manufacturers for space equipment needed for such projects.

The PRICE system, which is a unique package, has been marketed in the United States by its owner R.C.A. Price Systems, with very considerable success. There are currently over 60 major users in the U.S. aerospace industry including NASA and all the U.S. defence procurement agencies along with such household names as General Electric, Motorola, Goodyear and Lockheed.

Recent talks and usage of the PRICE system in both Europe and the Near East, have proved the PRICE system to be an equally effective management tool in these areas as in the United States. In the long term, the PRICE system, although developed originally for the aerospace industry, may well find wider markets.

Atkins On-Line is part of U.S.-based On-Line Systems Inc., of Pittsburgh, Pa. With its head office at Epsom, Surrey, Atkins On-Line has a network of access and communications points throughout the United States, United Kingdom and in Canada and Holland.

RUSSIANS PRAISE 'SPACEFLIGHT'

Moscow Radio broadcast a commentary by Boris Belitsky on 18 July 1979 dealing with the benefits of space cooperation with Britain and France, writes Julian Popescu. Belitsky praised British "significant scientific results, such as the Ariel 3 satellite" and cooperation between British and Russian scientists. He went on to say that interesting ideas had also "emerged" from the British Interplanetary Society "which publishes a fine journal *Spaceflight.*"

'OUR BEAUTIFUL EARTH'

An exhibition of aerial and space photography at the Smithsonian Institution's National Air and Space Museum in Washington, D.C., called "Our Beautiful Earth: The View from Air and Space," will remain open until early May, 1980, writes James Sweeney and Thecla Fabian. Half of the exhibition is devoted to views of the Earth from manned and unmanned spacecraft. The other half covers the history of aerial photography, and the work of four aerial photographers, Robert Bucknam, William Garnett, and Georg Gerster, who use small aircraft, and George Hall, who used the Goodyear blimp.

1966 marked the first time that a spacecraft turned its camera back towards Earth from remote space. The photo was transmitted to Earth from NASA's Lunar Orbiter spacecraft. A reproduction of this historic photograph is included in the NASM collection.

Early in the U.S. manned space flight programme, astronauts used hand-held cameras to photograph our planet from the windows of their spacecraft. They took photographs of land features and oceans during the Mercury, Gemini, Apollo and Skylab programmes, and the Apollo-Soyuz Test Project.

At the same time, aircraft were being used in tests of high altitude imagery using multispectral scanners. The combination of aerial and space photography resulted in the concept of a global data acquisition system consisting of a multi-spectral scanner mounted on a satellite. This was ultimately to lead to the experimental Landsat programme.

The Landsat satellites circle the globe 14 times a day in a near polar orbit at an altitude of some 917 km (570 miles). They scan, measure, collect and send back images of Earth which are used for such purposes as mapping remote areas and poorly charted regions, prospecting for minerals, searching for water in arid lands, and monitoring crops and timber.

The Smithsonian exhibition includes a number of examples of the early photos obtained from space. There is a picture of Hurricane Gladys stalled west of Naples, Florida, taken from Apollo 7 in 1968. Another picture taken from Apollo 7 shows the Himalayan Mountain Range. Even from Earth orbit, the Himalayas are a prominent feature on the Earth's surface.

The Landsat photos show how sophisticated space photography has become in the last ten years. Here are displayed photographs of the Earth with computer enhancement to pick out and emphasize selected features. One of the first displays the visitor sees upon entering the hall is a television screen showing a Landsat view of four storm systems. The picture is done in computer-enhanced full colour, which in this sense is of no real use scientifically, but it does make a pretty picture.

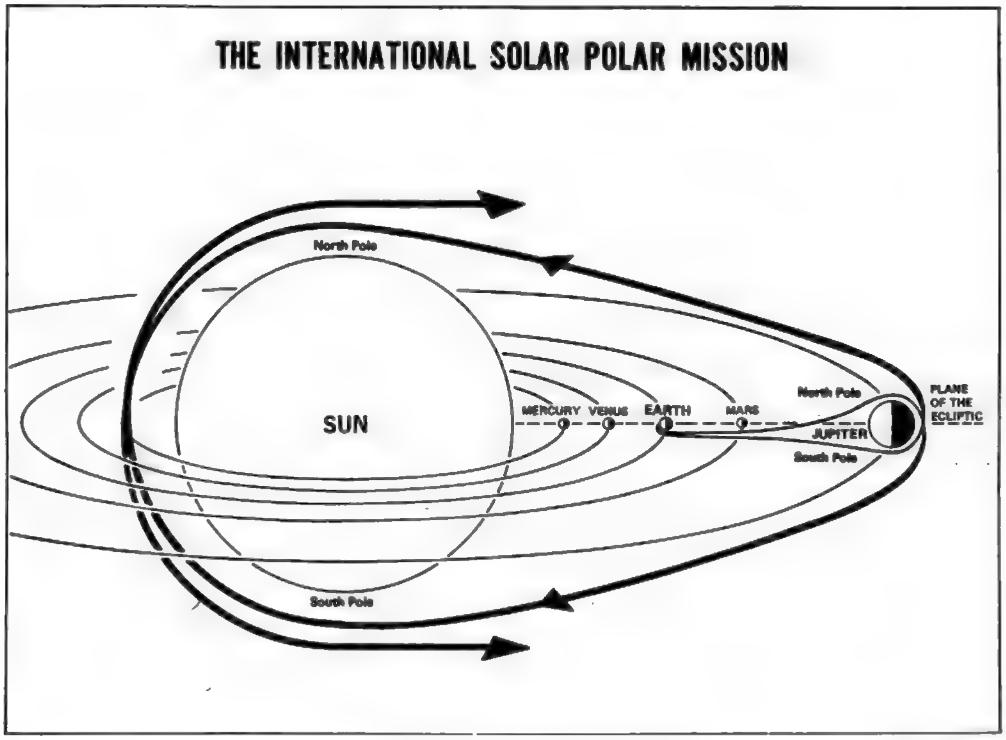
What comes across strongly is the way in which aerial and space photography have changed the way we look at our planet. It is only with Landsat that we are able to trace diseases as they kill off vegetation in remote sections of the world, or spot a developing crop failure. It is only with remote sensing that sources of air and water pollution can be traced, and we can see just how far this pollution can spread. Photography from air and space has become indispensible to cartography, urban planning, geology, military strategy, agriculture – yes, and even art!

BRITAIN JOINS 'INTERPLANETARY CLUB'

British Aerospace Dynamics Group at Bristol are to play a vital role in an international deep space mission to examine the poles of the Sun. Working with the prime contractor Dornier Systems on this £31 million project, the group will develop the equipment that controls the spacecraft's attitude and trajectory during a demanding four-year mission which will take it around Jupiter and over the Sun's poles.

The British company has responsibility for a £4 million share in this exciting new project and negotiations are continuing with Dornier which could result in additional work.

The spacecraft will be developed and built by the STAR



INTERNATIONAL SOLAR POLAR MISSION. Two sister ships, one built by TRW for the Jet Propulsion Laboratory, the other provided by the European Space Agency, will fly 'mirror image' orbits around Jupiter to get a gravity-assisted boost toward the Sun. Each will swing around the Sun, crossing over and under the poles, one spacecraft travelling from north to south and the other in the opposite direction.

TRW Inc.

Consortium for the European Space Agency which is supplying one of the two interplanetary probes in the International Solar Polar Mission (ISPM). The other is being provided by NASA.

The two craft are due to be launched towards Jupiter in early 1983. The strong gravitational pull of the giant planet then will be used to accumulate them out of the ecliptic plane in which Earth and the other planets orbit the Sun, so that one will pass over the north and the other over the south pole of the Sun.

This will be the first time that a space probe has been out of the plane of theecliptic, thus making it possible to examine the Sun's polar regions which cannot be seen from Earth or satellites in Earth orbit.

The mission is expected to improve understanding of the structure and dynamics of the solar corona, and solar wind particle flow from the Sun, magnetic fields and electromagnetic radiation of the Sun and of galactic sources. It also marks the entry of Britain into a select company – the 'interplanetary club.'

TILE CHECKS IN ORBIT?

NASA is to speed up development of the Manned Manoeuvring Unit that will allow an astronaut to inspect and repair the Space Shuttle's heat resistant tiles while in orbit. The unit will also allow numerous other activities outside the spacecraft that may require the personal attention of an astronaut such as spacecraft servicing and repair, payload replacement and rescue operations.

The Manned Manoeuvring Unit, built by Martin Marietta Aerospace, is an improved version of a gas-jet manoeuvring backpack test flown inside the Skylab orbital workshop during the second and third astronaut visits in 1973-74. It has been continuously updated and adapted since then.

NASA believes that inspection and repair of tiles should not be required on the first Shuttle orbital flight, designed to cause lower than normal stress, because the tiles will have been proof tested throughout the full range of stress expected during normal operational flight.

NASA decided to develop this capability now so that it will be available on later orbital flight tests when the launch environment will be up to design level and inspection and repair can be performed if conditions prove more severe than now predicted.

The first Shuttle orbital flight is now anticipated between the end of March and July 1980. The second flight should occur four months later. The Manned Manoeuvring Unit should complete development by August.

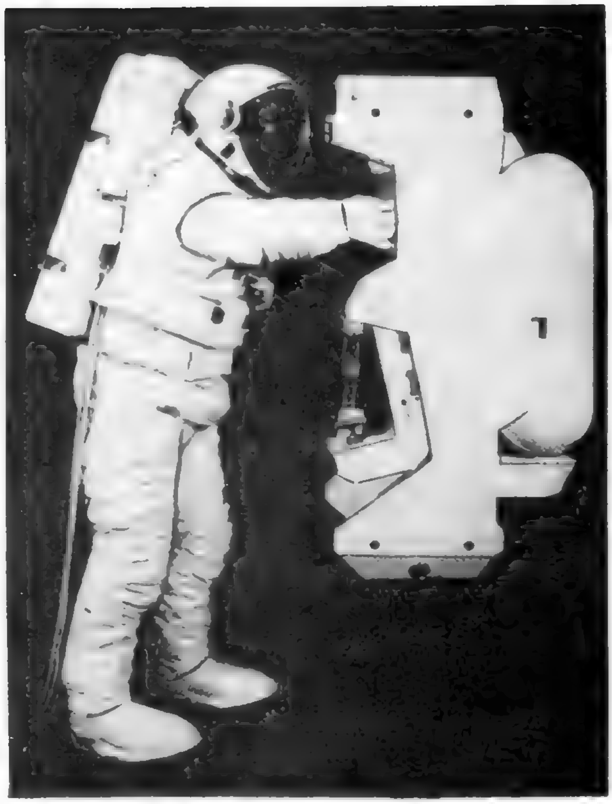
An alternative method of tile inspection, that of an extendable boom and television camera attached to the Shuttle's remote manipulator system,has been abandoned.

In addition to the manoeuvring unit, NASA will continue to examine, for at least another month, the feasibility of stabilized television units being placed in orbit by the Shuttle.

The orbiter would manoeuvre around the television cameras for a closed-circuit tile check by the orbiter crew.

Thousands of heat-resistant tiles cover the underside and sides of the orbiter. If any tiles are damaged during launch, they may have to be repaired before the orbiter re-enters the Earth's atmosphere. An astronaut using the manoeuvring unit would use one of the tile repair methods being developed to repair any damage to the heat shield.

Last October NASA began a series of pull checks to assess the strength of several thousand tile bonds. The tests involved monitoring the sounds made as a tile pulled outward under pressure. Analysis of the sounds made by the tile under stress enabled engineers to determine if each tile has adequate strength.



SPACE REPAIR KIT. 'High fidelity' mockup of the Manned Manoeuvring Unit designed to give astronauts the ability to move around and work outside the Space Shuttle Orbiter.

NASA

Tests of the tile have also begun using F-15 and F-104 aircraft at the Dryden Research Center in California. To achieve this the aircraft performs manoeuvres which demonstrate tile performance up to 140 per cent of the dynamic pressure planned for Shuttle operations.

The tests, however, will not check tile reaction to acoustic noise, vibrations, heating and local shocks the tile may have to endure during actual launch. These environmental factors are being separately tested in various ground facilities.

The Air Force's Arnold Engineering Development Center at Tullahoma began wind tunnel testing of the tile last November.

FRENCH NATIONAL COMSAT

SA Engines Matra has received a multi-million dollar contract from the French Government to develop and build three TELECOM 1 satellites the design of which will be based on the ECS spacecraft platform.

TELECOM 1, which will provide a national telecommunications service for France and its territories, is to be placed in Clarke (geostationary) orbit from Kourou, French Guiana, by an Ariane launcher at the turn of 1982/3. The programme provides for one operational satellite, with one in-orbit spare and one spare held in reserve on the ground.

The Stevenage Space Division of British Aerospace Dynamics Group has been given the responsibility for providing the power sub-system, the electrical distribution sub-systems and two solar array drive units for each satellite. This work is worth about 2.5 million pounds to British Aerospace Dynamics Group.

SPACE AFFAIRS

• Government • Policy
• International • Industry
• Economics

ECONOMIC EFFECTS OF SPACE

Investment in high technologies raises issues of increasing importance for the industrial nations; and is also becoming a matter of active concern in the developing world.

Government "think tanks", planning and finance ministeries, private and public institutions, and technological agencies, both national and international, spend a great deal of time and money in trying to determine the best route to take in the high technologies to attain the highest economic and social return, and they have developed a wide variety of techniques and methods to provide answers to the questions.

Now, for the first time in Europe, those who use these techniques will be meeting to discuss, review and compare their problems, methods and results. Organised by the European Space Agency and the University Louis Pasteur of Strasbourg, and co-sponsored by the Parliamentary Assembly of the Council of Europe, the International Colloquium on the "Economic benefits of space and other advanced technologies" will be held in Strasbourg on 28-30 April 1980. It will bring together economists, forecasters and technologists in government, research establishments, universities, the science and industry, from Europe, the USA and elsewhere in order to present analyses of research policy, surveys of the methods employed to evaluate progress, and descriptions of applied studies in the field.

The Colloquium will be of particular interest to all those engaged in formulating national and international strategies and policies in science and technology and their economic return.

ROCKETS AND BALLOONS

A Symposium on European rocket and balloon programmes and on related research, organised by the Science Research Council, Appleton Laboratory, UK, and the European Space Agency will take place on 14-18 April 1980 at the Heathlands Hotel, Bournemouth, United Kingdom.

This Symposium will be the fifth in a series of Symposia arranged since 1973 for the purpose of contributing to the harmonisation of European scientific sounding rocket and balloon programmes carried out at the Scandinavian ranges; the subjects dealt with also include related facilities and programmes that need to be taken into account when planning or executing these rocket and balloon programmes.

Experience at other ranges which could be relevant when considering experiments, programmes and facilities at Esrange or Andoya are also included in the Symposia.

Scientists and technologists are given the opportunity to report on their latest achievements, and also to put forward ideas for new experiments. The scientific emphasis in the 1980 Symposium will be on solar-terrestrial physics.

A unique feature of these Symposia is that they are gatherings to establish contacts among administrators, technologists and scientists.

The Symposium programme will be drawn up by the ESA Programme Advisory Committee on the Special Project for the launching of sounding rockets.

The Symposium will comprise the following sessions: European sounding rocket and balloon programmes; Middle Atmosphere Physics; Coupling between magnetosphere and ionosphere; Other research facilities, such as EISCAT and Spacelab/Shuttle; Material Science; Astrophysics; Range facilities, and Technology.

Persons wishing to take part in this Symposium should contact: The Secretariat for the Programme Advisory Committee on the ESRANGE Special Project, Application Programmes Department, European Space Agency, 8-10 rue Mario Nikis, 75738 Paris Cedex 15, France.

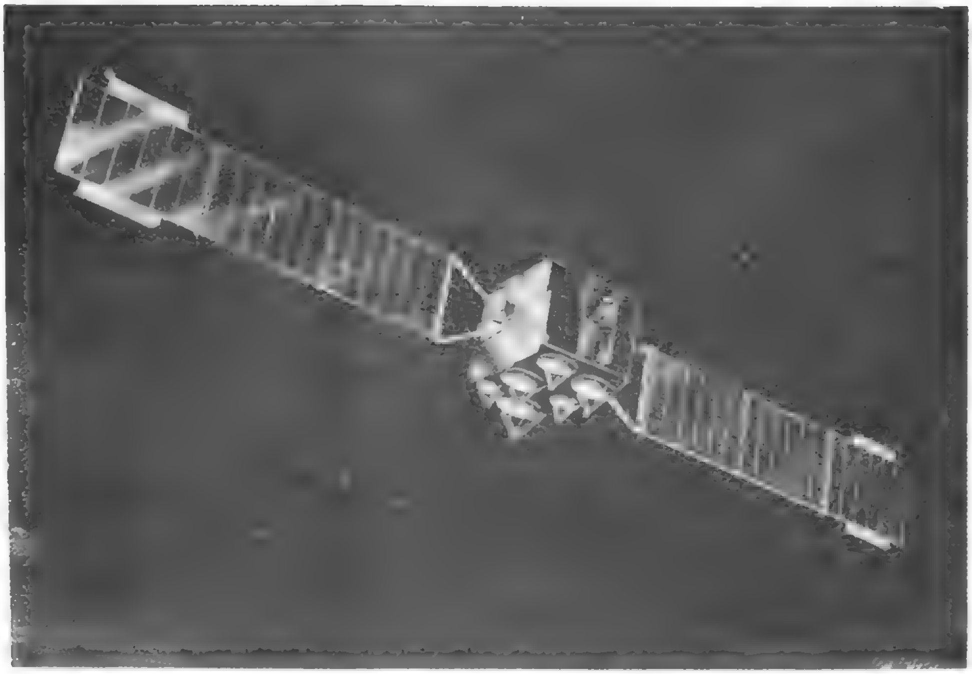
THIRD MARITIME SATELLITE

At a meeting in Paris of the Joint Board on Communication Satellite Programmes on 26 July 1979 the Member States participating in the MARECS programme agreed, pending a final decision by Immarsat on the configuration of its world-wide maritime space segment, to pre-finance the third ESA maritime communications satellite (Marecs-C), which is an integral part of the ESA offer to Inmarsat. This decision authorises the Agency to place a contract with the satellite prime contractor (BADG) for an amount of approximately 25 MAU and to take certain interim measures for provision of the Pacific Ocean ground station required for this programme.

The ESA Council, meeting on 25 July, decided that the agreement reached previously, under which the Marecs A and B satellites were to be offered to Inmarsat *via* Interim Eutelsat, could be replaced by a simpler arrangement whereby ESA would offer the three Marecs satellites directly to Inmarsat.

New ideas for balloon and sounding rocket experiments will be presented at the Bournemouth Symposium in April. Picture shows the British three-stage Skylark 12 rockets launched in a coordinated British/German scientific campaign to investigate the Northern Lights at Andoya, Norway.

British Aerospace



The European Space Agency's European Communications Satellite (ECS) – the fully operational regional communications satellite system which will carry a significant proportion of future European telephone, telex and TV traffic. The first ECS is scheduled to be launched by Ariane from Kourou, French Guiana, into Clarke (geostationary) orbit in 1981.

British Aerospace

NEW ECS CONTRACT

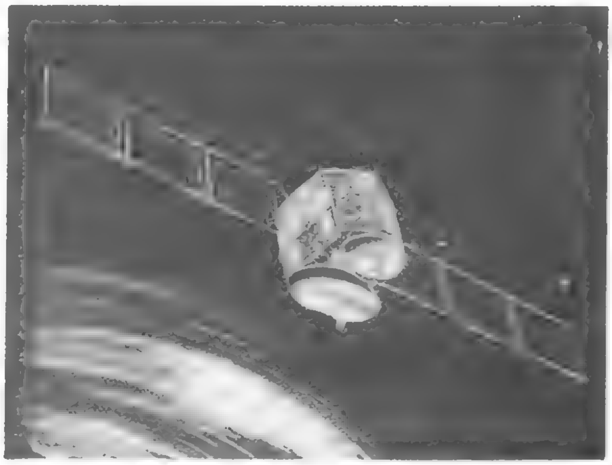
An order worth £37 million has been received by British Aerospace Dynamics Group from the European Space Agency for a further three European Communications Satellites (ECS). This brings to five the total number of ECS's to be built, which represents the largest satellite procurement ever made in Europe.

The five satellites, each of which should have a minimum operational lifetime of seven years, will provide Europe with its own communications system for relaying telephone, telex and TV traffic. They will also provide the main channel of communications for the Eurovision network.

Communication coverage will extend from the southern and eastern shores of the Mediterranean, including the Atlantic islands, and to Iceland and Scandinavia in the north.

The satellites are all to be launched by Ariane from Kourou, French Guiana, the first scheduled to go into orbit in 1981 and the second in 1982. These two will provide the initial service. The subsequent satellites will ensure continuity of service into the 1990's.

British Aerospace received the order as prime contractor of the MESH Consortium which includes MATRA (France); ERNO (West Germany); SAAB-SCANIA (Sweden); AERITALIA (Italy); FOKKER-VFW (Netherlands), and INTA (Spain).



Proposal for Arabsat based on ESC technology. In another development SA Engines Matra recently received a multi-million dollar contract from the French Government to develop and build three TELECOM 1 satellites to be based on the ECS spacecraft platform.

British Aerospace

ESOC APPOINTMENT

The Council of the European Space Agency has appointed Dr. Reinhold Steiner as director of the European Space Operations Centre (ESOC) at Darmstadt, which is responsible for control and tracking of the agency's satellites.

Dr. Steiner, 51, of Swiss nationality, has a degree in Chemical Engineering from the Swiss Federal Institute of Technology (ETH) in Zurich, a Diploma of the Imperial College, London and a Ph.D. in solid state physics from the University of London.

After some years in industry, he became Scientific and Technical Counsellor at the Swiss Emassies in Washington and Ottawa and later Counsellor for Space and Telecommunications Affairs at the Embassy in Washington. At the same time, he was a full member of the Board of Governors of INTELSAT. In 1973, he founded INTECO Ltd., a firm of consultants based in Washington dealing with different projects in the space field.

ESA AND REMOTE SENSING

The first important steps in preparing a European remote sensing satellite programme were taken by the Remote Sen-

[Continued on page 44

SATELLITE DIGEST - 133

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. A detailed explanation of the information presented can be found in the January, 1979 issue, p. 41.

Continued from the December issue]

Name designation object number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch site, launch vehicles and payload/launch origin
Westar 3 1979-72A	1979 Aug 10.014 indefinite	Cylinder 572	1.56 long 1.91 dia		geostationary orbit			ETR Delta Western Union/NASA (1)
Cosmos 1120 1979-73A	1979 Aug 11.39 13 days (R) 1979 Aug 24	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.4 dia?	169	361	70.56	89.85	Plesetsk A-2 USSR/USSR (2)
Cosmos 1121 1979-74A 11487	1979 Aug 14.65 30 days (R) 1979 Sep 13	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.4 dia?	170 165	346 305	67.16 67.14	89.70 89.22	Plesetsk A-2 USSR/USSR (3)
Cosmos 1122 1979-75A 11491	1979 Aug 17.32 13 days (R) 1979 Aug 30	Sphere-cylinder- cone? 5500?	5 long? 2.4 dia?	212	238	81.34	89.06	Plesetsk A-2 USSR/USSR (4)
Cosmos 1123 1979-76A	1979 Aug 21.47 13 days (R) 1979 Sep 3	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.4 dia?	210	232	81.36	88.99	Plesetsk A-2 USSR/USSR
Cosmos 1124 1979-77A 11509	1979 Aug 28.00 12 years?	Cylinder-cone + 6 panels + antennae? 1000?	3.4 long? 1.6 dia?	566 570	40259 39796	62.99 62.98	727.33 718.00	Plesetsk A-2-e USSR/USSR (5)
Cosmos 1125 1979-78A	1979 Aug 28.04 120 years?	Cylinder? 750?	2 long? 1 dia?	782	811	74.05	100.84	Plesetsk C-1 USSR/USSR
Cosmos 1126 1979-79A 11515	1979 Aug 31.47 14 days (R) 1979 Sep 14	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.4 dia?	378	394	72.86	92.31	Plesetsk A-2 USSR/USSR
Cosmos 1127 1979-80A 11520	1979 Sep 5.43 13 days (R) 1979 Sep 18	Cylinder + sphere + cylinder-cone? 6000?	6 long? 2.4 dia?	213 254 262	271 267 273	81.35 81.34 81.34	89.41 89.78 89.92	Plesetsk A-2 USSR/USSR (6)

Supplementary notes:

(1) Domestic US communications satellite, located above longitude 91° west. The satellite is owned by the Western Union Telegraph Company and was built by the Hughes Aircraft Company.
(2) Manoeuvrable, recoverable satellite.
(3) Orbital date are at 1979 Aug 15.5 and Sep 12.8.
(4) Cosmos 1122 carried an Earth Resources package.
(5) Probably a military early warning satellite. Orbital data are at 1979 Aug 28.6 and Sep 4.1.
(6) Orbital data are at 1979 Sep 5.6, Sep 12.7 and Sep 13.0.

Amendments:

1970-24A, Cosmos 330 decayed 1979 Jun 12, lifetime 3353 days.
1977-49A, Signe 3 decayed 1979 Jun 20, lifetime 733 days.
1979-9A, Ayame – add a second orbit at the end of August of 31 355 x 36 856 km, 0.4 deg, 1351 minutes. The satellite was damaged by a collision with the final stage of its launcher and is consequently no longer operating.

SPACE AFFAIRS/*Continued from page 43]*

sing Programme Board of the European Space Agency (ESA) late last year. The Programme Board approved the start of a Remote Sensing Preparatory Programme to be carried out by ESA. The Governments of Denmark, France,Italy, Netherlands, Sweden and United Kingdom have already subscribed to this new European venture, and additional Member States are expected to join in the near future.

The objectives of the new programme are to undertake the study and early development of critical technological systems needed by the future European remote sensing satellites, expected to be launched in the mid-eighties, monitoring both land and ocean surfaces. The tasks carried out by ESA will concentrate on the definition and pre-development of key elements of the optical and microwave sensors required for these future European satellites. Additional studies will examine in detail the interfaces between the remote sensing payload and a common satellite platform.

An important feature inherent in this new ESA activity is the direct utilisation of relevant developments underway within the national programmes. In this way all participating States benefit from the ongoing national initiatives. Specific examples of national developments from which the European systems will be wholly or partly derived include the multi-mission platform being developed by CNES for the SPOT satellite and the Synthetic Aperture Radar (SAR) studied in Germany for flights on Spacelab commencing in 1983.

The duration of the preparatory programme will be 2 years with an overall budget of 9 MAU. The programme will be incorporated into the larger remote sensing satellite development programme which is expected to be approved by the ESA Council in 1980.

25 Soviets launch Vostok-type bio-satellite Cosmos 1129 from Tyuratam into orbit of 226 x 406 km x 62.8 deg; period 90.5 min. in first experiment to breed mammals in space. International payload includes experiments from USSR and Intercosmos countries, United States and France. Major experiment consists of 38 white rats prepared by Soviet and Bulgarian scientists. Placed in orbit for about three weeks, the animals "will be studied upon return for the effects of weightlessness on their physiology." The Soviets will conduct the breeding experiment, separating male and female rats until the second day of flight, when the divider between the cages will be removed. In addition 60 Japanese quail eggs will begin incubation on the eighth day of flight. Resulting embryos will be studied on recovery, some being allowed to reach maturity. Materials from the United States include carrot seeds and embryos, carrot slices inoculated with bacteria which can form tumours in plants, and film and plastic capable of detecting radiation encountered in space.

25 Marshall Space Flight Center anticipates "a major milestone" during the sixth flight of a Space Processing Applications Rocket (SPAR). The significance of the flight is that it will carry the first experiment in space to process glass in a 'free-floating' state without a container. The experiment will attempt to form a bead of pure glass as a beginning that scientists hope will produce better quality optical glass. To provide the high temperature required for producing glass and to achieve purity desired for the material, a new acoustic leviator furnace has been developed by MSFC. The furnace, designed to attain temperatures up to 1575 deg C, uses sound waves to keep the material from touching, and being contaminated by, the walls of a container during the melting and cooling process.

26 Announced that Royal Aircraft Establishment, Farnborough, has been selected by NATO to manage the purchase of the Organisation's future communications satellites.

26 ESA Industrial Policy Committee approves choice of prime contractor, Dornier System (Germany), leader of the STAR consortium, for the development of the European spacecraft that will participate in the International Solar Polar Mission (ISPM), a cooperative project between ESA and NASA. Co-contractors are: Thomson-CSF (France) – telecommunications; FIAR/Montedel (Italy) – power and data processing system; Fokker (Netherlands) – thermal system; SENER (Spain) – mechanical systems; LM Ericsson (Sweden) – antenna; Contravés (Switzerland) – structure, and British Aerospace (UK) – attitude and orbit control system (AOCS). The contract will cover both the detailed design (phase B2) amounting to 680,000 AU, and the development, manufacture and testing (phases C and D) amounting to 46.5 MAU).
** Mid-1979 prices. AU: Accounting Units, 1 AU = 1.2 U.S. dollars.*

26 Soviets launch Vertikal 8 sounding rocket from Kapustin Yar to observe short wave solar radiation. The payload separated at a height of 100 km (62 miles), ascending to a zenith of 505 km (313 miles). On the descent leg of the trajectory of recoverable capsule separated at 95 km (59 miles), landing by parachute.

October

2 NASA announces that development of the Manned Manoeuvring Unit (MMU) is to be accelerated as a means of allowing an astronaut to inspect and repair the Space Shuttle's heat resistant tiles while in orbit. The MMU, built by Martin-Mareitta Aerospace, is an improved version of a gas-jet manoeuvring backpack flown inside Skylab during the second and third astronaut visits in 1973-74 (see 'Manned Manoeuvring Units', *Spaceflight*, June 1979, pp. 252-254).

3 Stevenage Space Division of British Aerospace Dynamics Group announces that it has been given the responsibility for providing the power sub-system, the electrical distribution sub-systems and two solar array drive units for the three Telecom 1 communications satellites being built by SA Engines Matra. The contract to BAe is worth about £2.5 million.

9 NASA announces that a new Headquarters programme office has been established to be responsible for operations of the Space Transportation System. The new office will have charge of Space Transportation System operations and functions including scheduling, manifesting, pricing and launch service agreements, the Spacelab programme, and NASA's expendable launch vehicles, except for development of Space Shuttle upper stages.

13 Re-entry capsule of Cosmos 1129 bio-satellite containing live rats, quails eggs, insects, plants and cell preparations, soft-lands in Kazakhstan after flight lasting 19 days. Throughout the flight, specialists on the ground received detailed information from the orbiting laboratory. After landing the test subjects on board had to be recovered very quickly, before they re-adapted to Earth gravity. The Soviet recovery team set up a field laboratory at the landing site comprising several linked inflatable 'tents.' Some dissections of rats were carried out on the spot and the remaining subjects were taken to the Moscow Institute of Biological Problems. There scientists from the USSR, Bulgaria, Hungary, the German Democractic Republic, Poland, the USA and France continued their examinations. After a preliminary study, some of the test specimens will be distributed to the laboratories of other countries participating in the experiments. Of particular importance are U.S. studies of animal muscle fibres and of animal bone formation and strength. These were expected to provide insights into the reasons for calcium loss in the bones and a loss of muscle strength experienced by astronauts and cosmonauts during prolonged space flights.

14 Following structural tests of the Space Shuttle Orbiter 'Challenger' at Palmdale, Lockheed-California confirms that the Rockwell-built vehicle conforms to specification for structural strength. This is another key step in the certification of the spacecraft for manned flight.
'Challenger' has since been returned to the Rockwell plant where it is being brought up to flight standard as one of the four operational vehicles. Ed.

16 NASA reveals that a new moon of Jupiter – the 14th – has been discovered by scientists studying photographs obtained by Voyager 2 during its close encounter with the planet last July. The moon, estimated to be 30 to 40 km across, orbits the giant planet at a distance of 57,800 km from the cloud tops.

CORRESPONDENCE

USSR National Exhibition

Sir, At the USSR National Exhibition, held at Earls Court from 23 May to 10 June 1979, several major Soviet space exhibits were on show. The centrepiece was a 1:1 scale model of the Soyuz 4 and 5 orbital "space-station" set up in January 1969. During that operation, the Soviet Union carried out the world's first orbital transfer from one manned spacecraft to another, when cosmonauts Yeliseyev and Khrunov space walked from Soyuz 5 to Soyuz 4, returning to Earth in the descent module of that spacecraft.

Other items on display included models of the Soyuz orbital and descent modules. The descent module was the 3-man configuration used prior to the Soyuz 11 fatalities in 1971, i.e. a model not used for over eight years. (The docking system on the Soyuz 4/5 vehicles had also not been used for over 10 years). One has to actually see the descent module to realise just how cramped it really is. The remaining manned spacecraft exhibit was a scale model of a launch pad at "Baikonur" i.e. the Tyuratam/Leninsk cosmodrome, complete with Vostok launcher.

Included in the interplanetary exploration section were models of the Lunokhod 2 moonrover, and the Luna 16 automatic station (complete with returnable lunar sample capsule), both displayed on a simulated lunar surface.

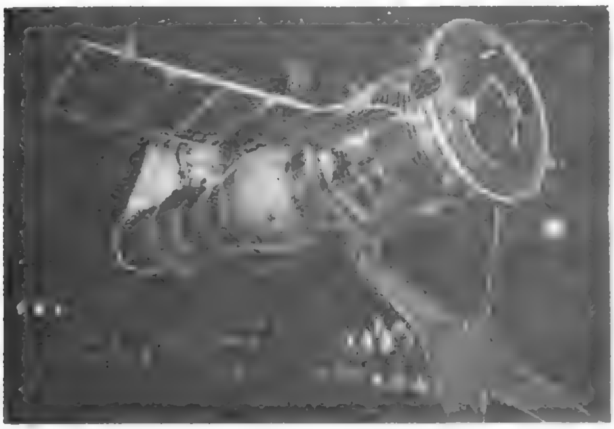
Other exhibits in this section featured a Venera capsule and a model of the Mars 3 automatic interplanetary station launched in May 1971.

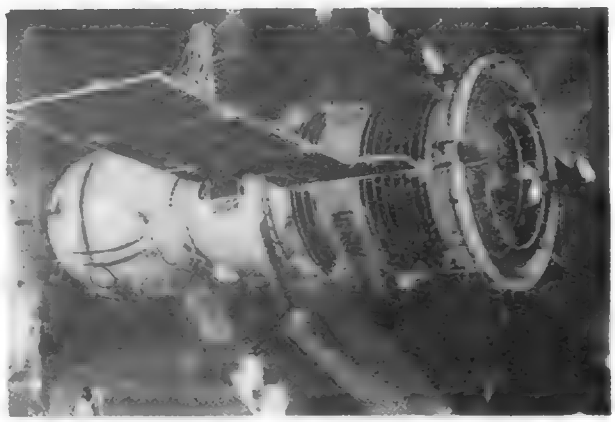
The final section, on international co-operation, included a display of photographs relating to the ASTP (Apollo/ Soyuz Test Project) and Intercosmos programmes. Actual exhibits included a model of the Cosmos 782 biosat, which carried biological experiments from seven countries including the Soviet Union and the United States. There was also a section of a Vertikal sounding rocket, and representations of a Molniya 2 com-sat and the Prognoz 2 satellite which carried out research into the Earth's magnetosphere.

The first USSR National Exhibition was held in the United Kingdom in 1961, and was visited by cosmonaut Yuri Gagarin shortly after his flight into immortality. No cosmonauts, however, were in attendance at this, the third such exhibition.

GORDON R. HOOPER,
88a, Connaught Avenue,
Frinton-on-Sea, Essex.

Copies of photographs may be obtained from the writer; s.a.e. for details. Ed.

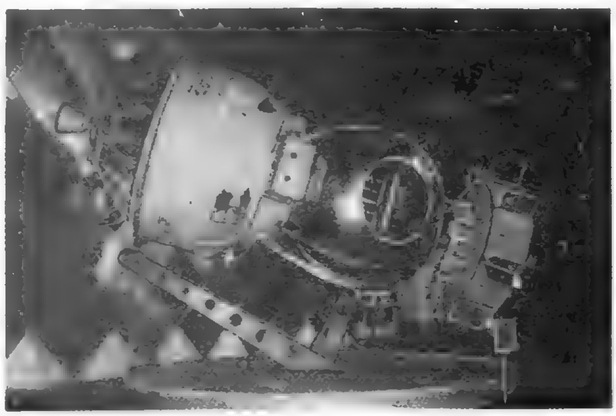




SOVIET SPACECRAFT. *Above*, replica of Soyuz 4/Soyuz 5 in docked configuration. *Below*, Soyuz re-entry module.

Above, Salyut spacecraft with solar 'wings.' *Below*, replica of Cosmos 782 biosat.

All photos Gordon R. Hooper



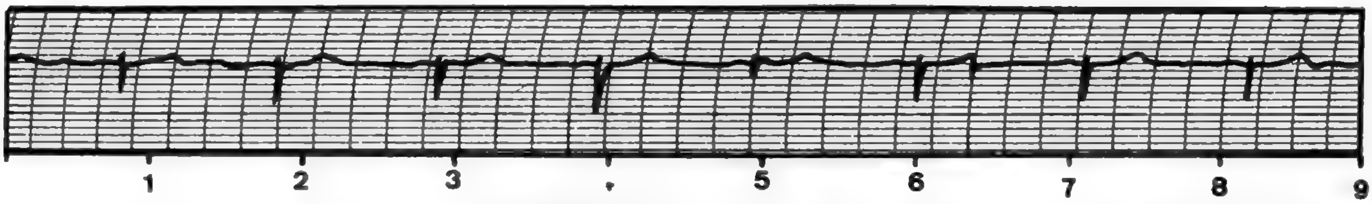


Fig. 1. Salyut 6 ECG.

Electro-cardiogram Transmissions from Salyut 6

Sir, An unusual tone-modulated signal was received on the Salyut 6 121.75 MHz FM voice link on 9 April 1979 in Fort Worth, Texas and again on 11 May 1979 in Stockholm, Sweden. The signal received was basically a quickly varying high-pitched tone with short and regularly spaced low-pitched segments. The signal was quickly identified as a signal channel of FM/FM telemetry using the voice transmitter as the radio link. By counting the low-pitched spikes it was found that they occurred about 60 times a minute which prompted speculation that the signal was actually some type of heart monitor channel. The signal received in Stockholm on 11 May was therefore fed through a frequency meter, the output of which was allowed to deflect the galvo pen of a strip-chart recorder. The resulting recording is shown in Fig. 1 and clearly looks like an electrocardiogram recording.

A careful analysis of the recording made in Fort Worth shows that the ECG signals came from an onboard cassette recording played back through the voice link. The start of the cassette recording clearly identified the source of the ECG as being cosmonaut Ryumin.

ECG telemetry was again received from Salyut 6 by Dieter Oslender in Bonn, Germany on 19 June 1979, and now seems to have become a regular feature of the present Salyut 6 mission.

Soviet sources have more or less confirmed that such ECG recordings have been made. In a *Tass* statement issued at mid-day on 11 May 1979 we can read:

"...today the cosmonauts are also working with the on-board documentation and doing physical exercises on the veloergometer and the trainer. According to the results of the medical checks, Vladimir Lyakhov and Valery Ryumin are in good health. The commander's pulse rate is 65 beats per minute and the flight engineer's 62 beats. Their blood pressure is, respectively, 130 by 65 and 130 by 70 mm of the mercury column."

SVEN GRAHN,
Sollentuna, Sweden.

MARK SEVERANCE,
Forth Worth, Texas, USA.

To The Executive Secretary

Sir, It is a pleasure for me to congratulate you and your colleagues with purchase of such a nice and comfortable building for the BIS Headquarters.

I share your hope that the BIS activities in the field of international cooperation will increase.

Accept my best wishes.

G. S. BALAYAN,
Scientific Secretary, Academy of Sciences of the USSR,
Council on International Cooperation in Research and
Uses of Outer Space "Intercosmos",
Moscow, USSR.

The Space Investors

Sir, Re: D. Baker; The NASA Budget (*Spaceflight*, August-September 1979). This is an excellent survey paper; it shows the real situation much more clearly than some of the very optimistic outlooks (O'Neill, or Powersat or even the next generation launch vehicles, etc.). In my opinion the heart of the problem is this: there is no industrial space activity of any size, compared to which the government funded space expenditures are small. This means of course, that so far we "space-cadets" have not succeeded in demonstrating that astronautics is basically necessary now (other than at a relatively small scale: communications, Earth observation, etc.).

Lest we Europeans feel superior to the "Bad Americans" I suggest re-reading the late Val Cleaver's superb "European Space Activities since World War II."

PROFESSOR HARRY O. RUPPE,
Technische Universität München,
München, West Germany.

Selecting the Polish Cosmonauts

Sir, The following information on the selection of Poland's first cosmonauts may be of interest to those who follow the exploits of the Cosmonaut detachments.

Following the agreement of the Socialist countries on 13 July 1976 to extend the Intercosmos programme to include manned space flights, the Polish Military Institute of Aviation set selection requirements as unspecified university studies, experience as a pilot and knowledge of the subjects of research [1]. Selection of candidates came from a group of several dozens, taking into account all the "intellectual predispositions." In August 1976 a group of 18 candidates, all military pilots, were selected all of whom met the demands of the programme.

The whole group then underwent a training and selection programme and from this came four successful candidates. These four started a two week series of tests on 10 November 1976 at the Yuri Gagarin Cosmonaut Training Centre in Star City. The Main Medical Commission of the Soviet Union then pronounced all four candidates fit to take part in the space programme. By a decision of the Polish authorities two were to undergo further training and preparation [2].

The two successful candidates were Major Hermaszewski and Lt. Col. Zenon Janowski whose flight occurred 27 June-5 July 1978. Hermaszewski was prime Cosmonaut researcher on Soyuz 30 and Janowski was named as Consultant to the Flight Controller, and served as Backup Cosmonaut researcher Soyuz 30.

It is possible that Janowski will fly the second manned Polish mission as Cosmonaut Researcher to a Salyut station with a Soviet commander; Hermaszewski will possibly be the backup to Janowski.

DAVE SHAYLER,
Small Heath, Birmingham.

BIS DEVELOPMENT PROGRAMME

PROGRESS REPORT

THE SOCIETY'S NEW LIBRARY

Filling the Library shelves in readiness for recording and classification.

Practically all of the equipment has now been delivered for our new library: the desks arrived quite recently, to provide a modicum of comfort for the Members of the Library Committee who are now able to hold their meetings in the library itself. Unfortunately, purchase of two display cases as part of the equipment has had to be deferred, owing to shortage of funds, as have also plans for an eventual slide display, for the same reason.

Once the main body of the library equipment arrived, purchased with the aid of a magnificent gift from Arthur C. Clarke, the problem then arose as to how to fill the library shelves. The Society's initial stock of books and reports was very small, (formerly our space consisted of only two small offices) but the core was substantially expanded by the gift of the entire collection of our Executive Secretary. Even so, there appeared to be acres of empty shelves remaining. Although a basic library began to emerge, it was still far below the threshold of viability, particularly since many of the books were rare and/or valuable, sometimes irreplaceable, and ought not to be exposed to the danger of damage or loss. Duplicate copies were, clearly, required, besides large numbers of technical reports and books needed to fill obvious gaps in the collection.

At an early stage it was decided that the library should aim to create a highly specialised collection of works on astronautics and space-related subject material which represented important advances in the state of the art. No attempt should be made to collect or retain popular works, a wide variety of which were already easily available from any public library.

With this initial policy settled, work began on preparing a detailed library layout and arranging and classifying books. Most of this work was done by Andrew Wilson: The headings on the library shelves were supplied by David Holmes. Mrs. Caroline Kenward emerged, as a qualified librarian, to undertake the detailed classification work on a part-time basis.

At the same time Max Wholey was appointed Archives Librarian, with responsibility for collecting and preserving material of historical interest on behalf of the Society, giving one full day each month to this. Later, Louise Parks emerged to assist Max in his depredations and rifling the correspondence files, books etc. of every Council member or long-standing member of the Society in sight.

Research into methods of classification presented quite a few problems. There appeared to be no consistency in the matter and, although there were several well known and widely adopted schemes, there was an equally large number of important exceptions. The concensus of opinion from those experts consulted appeared to be "Make up a scheme which suits your own requirements best!" This, in fact, left us precisely where we were before. However, by a stroke of good luck, Mr. George Chandler, Director of the NASA Scientific and Technical Office, emerged with some extremely valuable classification literature and the suggestion that the library be modelled on and made compatable with the libraries of both NASA and the European Space Agency. This appeared to be an ideal solution, since both organisations already had detailed classification lists which would enable subjects to be grouped together or cross referenced and, as both industry and government were already relying on the NASA-inspired system, it was desirable that the Society's library should dovetail this exactly.

Initially, of course, the number of books and reports available hardly warranted such an exercise, but it was clearly in the long-term interests of the Society that, from its earliest stages, the library scheme should be made compatable with that of the two main information-distributing agencies and that, with growth, the whole scheme would pay off handsomely.

Mrs. Kenward, accordingly, started work on familiarizing herself with the ramifications of the NASA system and, in due course, the preparation of catalogue cards. This developed into quite a substantial exercise. As the pile of indexed cards began to grow, order slowly began to emerge from chaos, with the appearance of a rudimentary information-retrieval system exciting to watch.

With this part of the work safely launched, the problem then arose about how to acquire a Library Stock with no funds available for such a purpose, especially since inroads already had to be made into the Society's funds for the acquisition of library "software."

A number of matters were decided upon. Firstly, members who undertake to review books for the Society would be asked if they would kindly return the books, subsequently, for the Society's library – even though the normal practice is for reviewers to keep these books after review! This is most important for, with individual books costing so much nowadays, it is the only way in which current books can readily be added to our Accessions List. At the same time, an Appeal was made to members, not only for suitable books and reports, but any other item of interest e.g. paintings, photographs, slides etc. which the Society would be able to use. A note about this appeared in *Spaceflight* for July, 1979 and was repeated both in *JBIS* and *Spaceflight* in following months. The response, so far, has not been overwhelming, but our grateful thanks are extended to those who *have* so far responded, often by going to some considerable trouble in order to help us. We are indeed most grateful to them. Since we need at least another thousand books plus a thousand Reports to make sure that adequate stock is available to every would-be library browser and that the shelves are not denuded by previous borrowers, one can see how important this is.

Matters were not, however, to be allowed to rest there. The Secretary was encouraged to embark on a one-man campaign to beg, borrow or use such other influence as he had, to encourage the donation of a steady flow of material to fill our shelves.

At the time of writing it is too early to say what the result might be, for these matters normally take some time to mature. Up to now, however, the response – both from members and non-members – has been most sympathetic and most encouraging.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 27/29 South Lambeth Road, London SW8 1SZ

Correspondence and manuscripts intended for publication should be addressed to the Editor, 27/29 South Lambeth Road, London SW8 1SZ.

Study Course
Title: **X-RAYS IN THE UNIVERSE**
by Dr. A. C. Fabian
To be held in the Golovine Conference Room, Society HQ., 27/29 South Lambeth Road, London, SW8 1SZ on **2 January 1980**, 6.30-9.00 p.m.
Registration is necessary. For further details apply to the Executive Secretary.

Technical Forum
This is the first of a new type of meeting in the Society's new building to enable small technical groups to discuss subjects of particular interest at a suitably high level.

To be held in the Golovine Conference Room, Society H.Q., 27/29 South Lambeth Road, London, SW8 1SZ on **4 January 1980**, 6.30-9.00 p.m.

Topic: **THE SOVIET SPACE PROGRAMME**
The Speakers will include the following:-

Phillip S. Clark	– The G Vehicle – Phoenix or Dinosaur?
Ralph F. Gibbons	– A Reappraisal of the Soyuz 1 to 9 Flights
David Hawkins	– Visual Observation of Soviet Spacecraft
Nicholas I. Porter	– The Soyuz Programme
Michael Richardson	– The Salyut 6 Mission

Members with a special interest in the Soviet Space Programme are invited to attend.

No fee is payable but registration *is* necessary. Forms are available from the Executive Secretary on request enclosing a reply-paid envelope.

Study Course
Title: **EVOLUTION OF STELLAR SYSTEMS**
by Dr. J. Jones
To be held in the Golovine Conference Room, Society H.Q., 27/29 South Lambeth Road, London, SW8 1SZ on **23 January 1980**, 6.30-9.00 p.m.
Registration is necessary. For further details apply to the Executive Secretary.

Study Course
Title: **FUTURE OBSERVATION IN COSMOLOGY**
by Dr. C. D. Mackay
To be held in the Golovine Conference Room, Society H.Q., 27/29 South Lambeth Road, London, SW8 1SZ on **6 February 1980**, 6.30-9.00 p.m. **(Please note revised date)**
Registration is necessary. For further details apply to the Executive Secretary.

Visit
A tour of the Astronomy and Space Galleries of the Science Museum, Exhibition Road, London, S.W.7, accompanied by Dr. John Becklake, will take place on **12 February 1980**, commencing at 6.30 p.m.

Admission (restricted to members only) will be by ticket available from the Executive Secretary on request enclosing a **reply-paid envelope.**

17th European Space Symposium
Theme: **ASTRONAUTICS IN THE NEXT 50 YEARS**
A three day meeting to be held at the Royal Commonwealth Society, London, W.C.2. from **4-6 June 1980**, sponsored by the BIS, AAAS, AIDAA and DGLR and co-sponsored by EUROSPACE.

Offers of Papers are invited. Please contact the Executive Secretary for further information.

Registration is necessary. Copies of the programme will be available in due course.

31st IAF Congress
The 31st Congress of the International Astronautical Federation will be held in the Takanawa Prince Hotel, Takanawa, Minato-ku, Tokyo, Japan from **21-28 September 1980.**

Members of the Society intending to present papers are asked to notify Dr. L. R. Shepherd, Chairman of the BIS International Liaison Committee at Society H.Q. as soon as practicable. Further information on the Congress will be published as it comes to hand.

Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published for The British Interplanetary Society Ltd., (No. 402498) by Space Educational Aids Ltd., (No. 741211). Registered Office, 27/29 South Lambeth Road, London, SW8 1SZ, England.

SPACEFLIGHT

VOLUME 22 No 2 FEBRUARY 1980

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SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 NO 2 FEBRUARY 1980 *Published 15 January 1980*

Editor
Kenneth W. Gatland, FRAS, FBIS

CONTENTS

COVER

GALILEAN MOONS. Photographed at close quarters by Voyager spacecraft last year, the Galilean satellites have been assembled into this magnificent collage by JPL scientists. They are not to scale but are in their relative positions. Io (upper left) is nearest Jupiter; then Europa (centre); Ganymede and Callisto (lower right). Nine other much smaller satellites circle Jupiter, one inside Io's orbit and the others millions of miles from the planet. Not visible is Jupiter's faint ring of particles, seen for the first time by Voyager 1. In this issue we focus on Ganymede, the largest moon (see page 72).

Jet Propulsion Laboratory, NASA

MILESTONES

October

17 Reports from Far East suggest that China is preparing to test an operational version of the CSS-X-4 intercontinental ballistic missile. Western observers believe that a prototype of the CSS-X-4 was responsible for launching China's recoverable observation satellites. A third stage employing liquid oxygen and liquid hydrogen propellants is being developed as a means of up-rating this vehicle.

24 Resumption of clustered Space Shuttle Main Engine (SSME) testing at the National Space Technology Laboratories, following July malfunction, is postponed for two weeks after discovery of "a small hydrogen leak" in the plumbing between the aft end of the simulated Orbiter and the SSME's. The previous delay followed a "fatigue failure" in the main fuel valve of one engine (See "Milestones" entry 12 July 1979).

30 NASA launches 181 kg Magsat by four-stage Scout from Vandenberg AFB, California, into orbit of 355×562 km inclined at 96.8 deg to equator; period 93.82 min. Object is to measure the Earth's near-surface magnetic fields and, indirectly, crustal features related to Earthquakes and mineral deposits.

November

4 A scheduled 510-second static firing of the Space Shuttle Main Propulsion System test article ends after 9 seconds at the National Space Technology Laboratories: An automatic cut-off of the three-engine cluster was commanded when a sensor detected excessive pressure in a seal cavity of the high-pressure oxygen pump of engine no. 3. Subsequently, engine no. 1 was damaged during the cut-off sequence. According to NASA, "the damage resulted when a hydrogen line ruptured near the base of the engine nozzle. The line carries hydrogen through the nozzle for cooling purposes before it enters the combustion chamber. The rupture resulted in a hotter-than-normal 'oxygen-rich' combustion which is likely to have caused substantial damage to the engine interior."

5 Mr. L. Michael Weeks, General Electric Company executive, becomes Deputy Associate Administrator for Space Transportation Systems Acquisition at NASA Headquarters, Washington, D.C. "In this position" (says NASA Associate Administrator) "he will play a key role in the development and acquisition of NASA's Space Transportation System, including the space shuttle, its upper stages, associated ground facilities and equipment and systems' improvements."

5 Reported from Canberra that British participation in the Anglo-Australian Woomera rocket range will end in June 1980 after 34 years.

7 UK Department of Industry contracts British Aerospace Dynamics Group at Bristol to lead a team of British companies to study the implications to industry of a Satellite Solar Power Station (SSPS) of the type proposed by Dr. Peter Glaser in 1968. Other participants in the six month study include Marconi Space and Defence Systems, ERA Technology and BAe's space group at Stevenage. Object: to explore a possible energy option of the 21st century (now being actively studied in the United States) whereby UK companies derive maximum benefit from any future SSPS projects developed on an international basis.

8 Reported in Washington that NASA has informed Congress that chances of Space Shuttle "Columbia" being launched in 1980 are: *April*, 10 %; *July*, 50 %; *September*, 90%.

15 NASA announces that testing of the Space Shuttle main propulsion system will resume about 14 December (see 4 November entry) using a different nozzle from the one which suffered the ruptured hydrogen line.

В журнале не печатается ряд страниц.

SALYUT 6 MISSION REPORT

By Neville Kidger

(Continued from August-September issue)

In this article, which begins the story of the flight of the long-stay cosmonauts Vladimir Lyakhov and Valery Ryumin, we include the first part of a quick-reference 'Daily Log' of activities. During the past 18 months the Soviet manned space programme has shown a remarkable determination, with the almost routine docking of supply craft – especially the versatile Progress automatic ferries – designed to keep stations operating long after they would otherwise decay from orbit. Ed.

Salyut 6 in Automatic Flight

Before leaving their home in orbit the *Photons*, Vladimir Kovalenok and Aleksandr Ivanchenkov, had cleaned its compartments and prepared it for its next visitors. Their final tasks included putting the flight control systems of the 13.5 metre long station into the automatic flight regime. In this mode the station returned data to the Kaliningrad Flight Control Centre (FCC) six times per day *via* the tracking stations located on the USSR's land mass. The five tracking ships which were stationed in the world's oceans during the flight of the *Photons* were recalled to their home ports following the successful recovery of cosmonauts Kovalenok and Ivanchenkov on 2 November 1978 after their record-breaking 139 day 14 hour 48 minute flight. One of the ships, the *Kosmonavt Pavel Belyayev*, had been on station for over 200 days in connection with the flight.

During the Salyut's automatic flight specialists at the FCC concentrated on controlling the station's thermal regime, energy reserves, orientation and attitude control. A Soviet report said that 'solar radiation, undiminished by the atmosphere, makes the casing and external parts (of the Salyut) very hot ...' although the casing is protected by a vacuum and screen insulating coat, the problem of eliminating heat (remains) difficult and serious'. The report also commented that in order to supply electrical energy to the many important mechanisms and systems during the period of automatic flight the station had to be oriented by means of the small attitude control motors; 32 of them are located in 4 clusters, one each at 90°, around the 4.15 metre diameter section. These manoeuvres enable the three sets of solar panels to recharge the electrical storage batteries. The flight controllers also conducted unspecified trials of "separate onboard systems, units and equipment". The parameters of the microclimate within the working compartments of the station were being maintained "within the planned limits".

By 1100 (GMT) on 29 December the station's orbit had dropped to one having a period of 91.2 minutes, from the 91.7 minute one the Progress 4 transport cargo craft had put the station into just before the end of the 140 day flight. The height of the orbit ranged between 337 to 357 km. The Salyut was at its nominal 51.6° inclination.

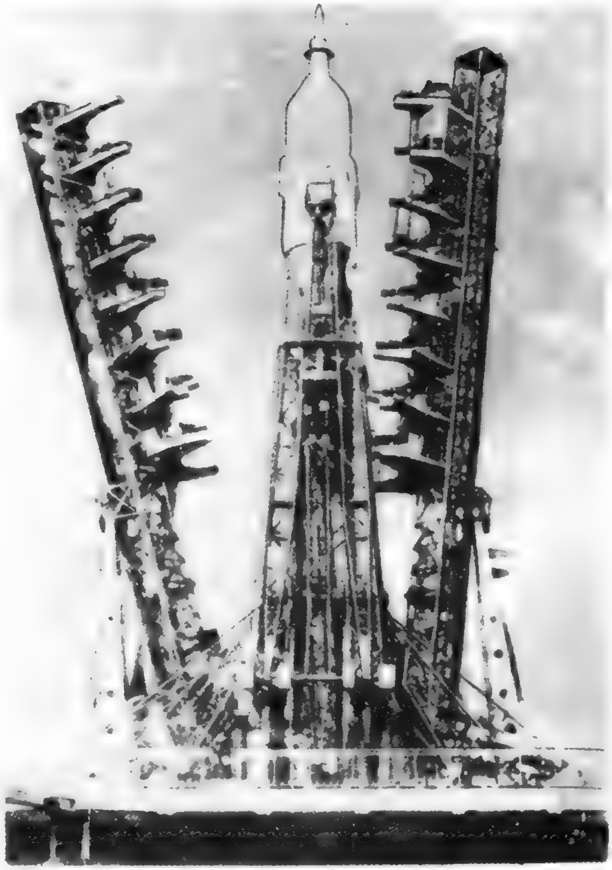
Early in January 1979 the Soviets reported that the main mission of the Salyut 6 station had already been fulfilled. The Soviet cosmonaut chief Lt. Gen. Vladimir Shatalov reported, on 15 January, that Soviet specialists were examining the possibilities of the station being able to receive other cosmonauts. He noted that crews with members from the USSR, Bulgaria, Hungary, Romania, Cuba and Mongolia were training for flights at Star City, near Moscow. Shatalov described the two Bulgarian candidates, for Radio Sofia, as "good, skilled pilots, charming people who (had) enjoyed an immediate, warm reception on the part of the Soviet spacemen. The Inter-Kosmonauts had, by 9 February, successfully completed their basic theoretical training and were now working in trainers ... as members of crews together with their experienced Soviet commanders who have flown more than once in space."

By 15 February the station's orbit had sunk to one with a period of 90.7 minutes, ranging in height from 307 to 330 km. It was anticipated by Salyut observers that a manoeuvre which would place Salyut 6 back into a nominal 91.4 minute orbit, similar to the one performed on command from FCC on 16 May 1978 prior to the commencement of the Soyuz 29 flight, would precede the launch of a manned flight to the station. Conditions within the station's working compartments were good: temperature 16°C.; pressure, 750 mm. Speaking on Radio Moscow's World Service Aleksandr Ivanchenkov said that the air in the station "at the moment is clean, calm and warm." The *Photons* had returned samples of the air inside Salyut which had shown that it was "quite satisfactory" for further habitation[1].

Vladimir Kovalenok, describing his sensations upon entering the Salyut for the first time, said that the station was in darkness until 'Sachet' Ivanchenkov turned on the lights. "The station looked cozy, exactly the way it looks now ... (now) it is quiet, indeed empty ... (but it is) ready to receive its next visitors at a moment's notice."

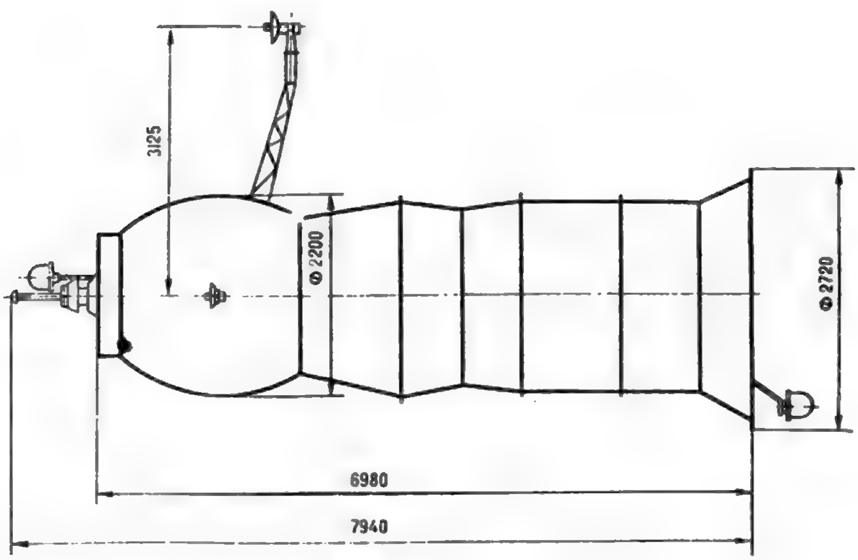
In early February the first indications were seen, in the deployment of Soviet military forces into positions they would normally occupy during manned flights, that a new crew was preparing to board the Salyut 6 space station. Some observers linked the activity with an anticipated Luna probe, noting that the Salyut had not made the anticipated manoeuvre to its optimum orbit. It was unclear whether this lack of manoeuvring activity was planned because the Salyut's fuel reserves were so low as to make it impossible, or whether the Soviets wanted to assess the condition of the station before deciding on the continuation of manned flights in it. If the station had degraded to the extent that it would not permit the 6½ month occupancy by two Soviet crewmen, with the 5 Intercosmos flights, then the remaining fuel reserves could be used to de-boost the Salyut over the Pacific Ocean. If the crew found that the Salyut was usable then it could be boosted into the nominal orbit by a Progress cargo transport spacecraft, being refuelled during the same visit[2].

Konstantin Feoktistov, Chief Designer of Soviet spacecraft, said that during the unmanned flight of the station its systems had been monitored *via* telemetry. Most of the systems, in particular the life-support, flight directional and power supply systems, had been found to be far from exhausted. Plans were therefore drafted for the next crew to Salyut to assess on-the-spot the condition of the station and its ability to receive more manned visits. Following the reactivation of the station the cosmonauts were scheduled to carry out a careful inspection, "in a definite order", of the operational capabilities of the about 1000 individual instruments and systems of the 19 tonne station. If an instrument's primary system was found to have failed the cosmonauts would switch to the reserve circuit, or, if the parts were available, replace the primary unit. The Soviets claimed that up to the launch of Soyuz 32 "not one reserve circuit in any system (onboard the Salyut) has been switched on," a statement clearly at odds with a report in *Komolskaya Pravda* at the beginning of February 1978 which said that prior to the Soyuz 27 docking the *Taymyr* crew, Romanenko and Grechko, had found that one of Salyut's four voice transmitters had malfunctioned and the cosmonauts had switched over to a reserve one. In another incident the *Taymyrs* had found the water reclamation system appeared to be losing water; although no mechanisms were involved in this "repair" the solution was found to be the absorption of water vapour in the wooden panels of the working compartment, which had been installed in the Baikonur MIK assembly building during the hot, dry summer of 1977.



1 and 2 These pictures show launch preparations for an earlier mission to Salyut 6, the one flown by Valery Bykovsky (USSR) and Sigmund Jaehn (GDR) in Soyuz 31.

Panorama DDR/Zentralbild



Progress spacecraft. Dimensions in millimetres.

Some specific items were scheduled to be replaced anyway, such as ventilators in the STR thermo-regulation system, lights, individual cables for the TV and communications equipment, components of the veloergometer and the running track and filters and regenerators of the life-support systems.

Such repairs were made possible because of the Salyut's design which, using modular 'plug-in' electronics units, provided for replacement of these individual systems. For example the *Photons* replaced the Globus (Globe) instrument panel, located on the main control panel, and new computer units for the Delta autonomous navigation system with identical units brought to them by the Progress 2 cargo spacecraft. The Soviets pointed out that although an item had to be replaced this did not mean that the equipment had broken down. Progress spacecraft had made it possible to provide replacement units for ones that were approaching the end of their planned operational life. It was considered prudent to replace those units for new ones than risk them breaking down later. During the assessment the crew would radio their requirements to the FCC and if the station was found to be perfectly usable a Progress ferry would be launched to bring the supplies to the orbital station. The final decision on the items would be left to the cosmonauts themselves.

Clearly the cosmonauts for this flight faced a major task. The Soviets chose a crew with only 2 days of spaceflight experience, and those days were on the Soyuz 25 abort. The crew commander was a rookie, Lt. Col. Vladimir Lyakhov, and his flight engineer civilian Valeri Ryumin. Both men were reserve for the Soyuz 29 flight.

Once in the Soyuz command cabin, strapped into their contoured seats, the cosmonauts were played music as they awaited the signal to launch. The cosmonauts, with their visors down and their gloves on were reliant on their small portable "climate boxes". B/W TV beamed to the Flight Control Centre at Kaliningrad showed the cosmonauts in the cabin. Soon the final command was given and the rocket's first and second stages lit up and began to build up the thrust to lift the rocket into the air. It was 1154 (all times in this report are GMT) on February 25th 1979 and the third long-term stay crew to Salyut 6 were on their way. About 2 minutes after the lift-off the rocket shed the four strap-on boosters surrounding the central core. The central core, with an RD-108 engine, was cast off at about 170 km altitude the third stage then took over to carry the Soyuz 32 spacecraft and its 2 man crew into an orbit ranging from 205×225 km. The *Protons* (their call sign) prepared for their first tasks, checking out the systems of the Soyuz, moving for a time into the Orbital Compartment.

Before the cosmonauts retired for the night the orbit of their spacecraft was altered by a burn of the Soyuz's 4kN thrust engine (probably on the 4th revolution), to one of 224×283 km with a period of 89.6 minutes. Both Soyuz 32 and its target, the Salyut 6 space station, were at an inclination of 51.6° to the equator.

The crew began their second working day in space at 0530. The crew prepared for their docking with the station. FCC controlled the flight until, following at least one more manoeuvre, with the TV camera of Soyuz beaming back pictures of their target, Lyakhov guided the Soyuz docking probe into the drogue of Salyut's forward docking unit. At 1330, 26 February, came the message "Yest Stikovka!" ("There's Docking!"). The Salyut 6/Soyuz 32 complex was in a 296×309 km orbit.

Following the standard checks of the rigidity and airtightness of the docking the *Protons* entered the station. Their first tasks were, as always, to switch on the internal lights and to mothball the systems of the Soyuz 32 ferry. They installed an air hose between the vehicles to facilitate the flow of air between the two vehicles. The fans of the Salyut ventilation system cause the air in the station to circulate at a speed of about 0.8–1 m/sec. and the station interior had the smell of a pine forest thanks to the 'Svezhest' air freshness system.

As the docking had used only half the fuel budgeted for it, the flight controllers took the opportunity to use the spare fuel to raise the orbit of the complex halfway to the nominal 91.4 minute orbit. The planned Progress resupply flight then would boost the complex the rest of the way. So it was, in the afternoon of 1 March the cosmonauts fired the engines of the Soyuz 32 spaceship to raise the height of the orbit by about 35 km. The new orbital parameters were 308×338 km×90.9 minutes. In a memorable slip-of-the-tongue on the Radio Moscow home service, FCC ballistics group leader Vladimir Gavrilov said that "in (the Salyut's) new orbit of 350 km the station's flight path takes it over the same area of the Earth every two days". The statement was soon corrected to read that the manoeuvre was "the first step to bring (the Salyut) up to 350 km – the most convenient orbit for an inhabited station".

Adaptation to Weightlessness

The first jobs for the *Protons* on Salyut 6 were to reactivate all of the station's life-support systems, a job completed by the end of the first week in orbit. These systems, the supply of air, water etc., were designed to provide the essentials of life in space but the major concern for the flight controllers of the first days was how the crew, with only 2 days of spaceflight activity behind them, coped with weightlessness.

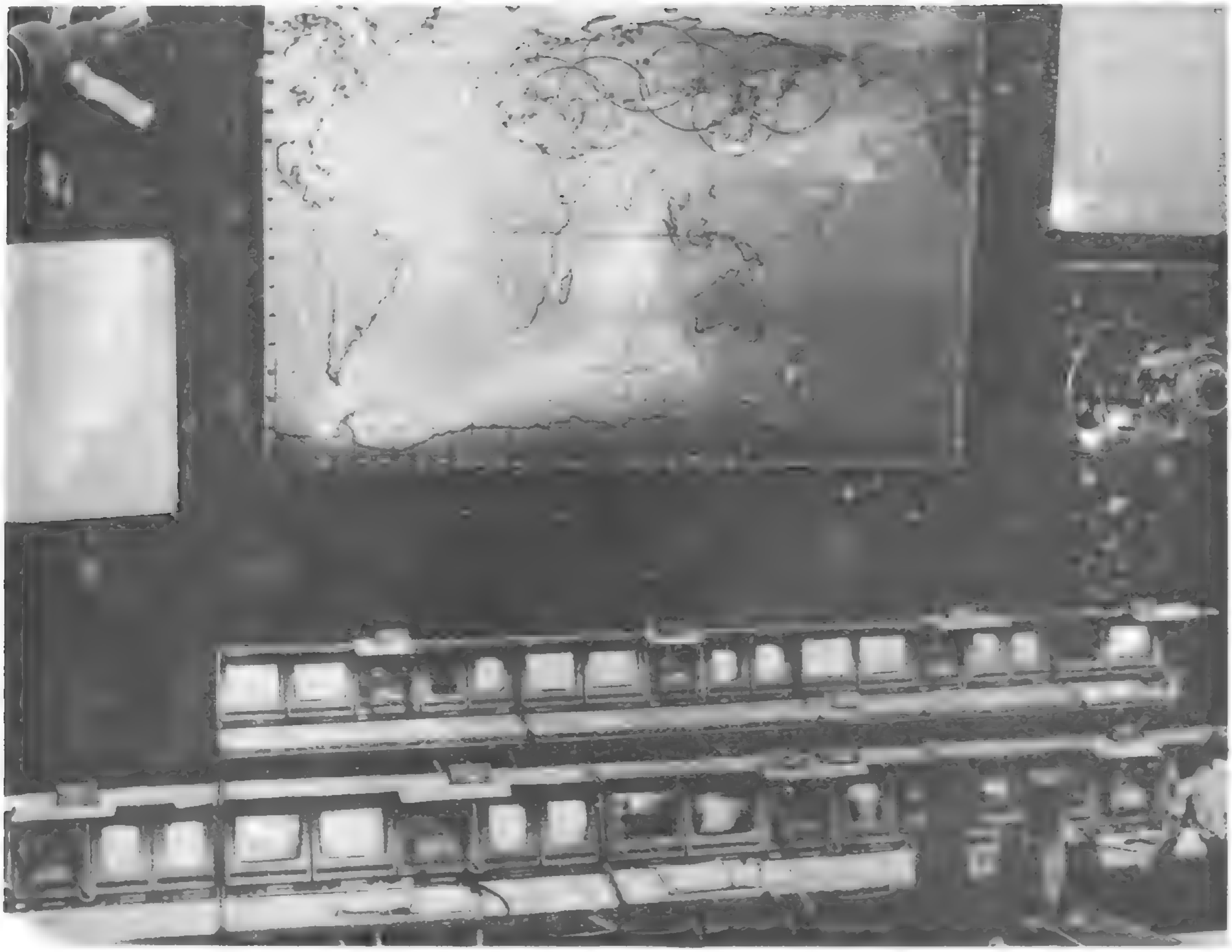
Soviet medical specialists noted from previous flights that there were three peak loads during the body's adaptation to the weightless state. These were: (1) the initial onset of weightlessness; (2) the "complex dynamic operations during docking and transfer"; (3) the emotional strain. From previous experience a standard schedule of tolerable loads during the first days of work in weightlessness had been drawn up. The aim was to enter the "cosmic rhythm without rushing".

Doctors concerned that Lyakhov, a solidly built person, might, on his first encounter with weightlessness, experience problems. They therefore concentrated the greater part of his pre-flight training programme on 'tuning' his vestibular system. Ryumin's training concentrated on maintaining a high degree of functioning of his cardiovascular system. The cosmonauts were given a complex cycle of training sessions which took account of the time factor and the number and duration of training sessions. The process of preparation ended only when the cosmonauts were strapped into their seats aboard Soyuz 32 on the launch pad.

Lyakhov experienced 1½ days of acute adaptation. However, towards the evening of the second day of the flight, settled in Salyut, he reported that the malaise had passed without his needing to resort to drugs or other medication. Ryumin, on the other hand, adapted well and no changes in his pulse rate, blood pressure or general state were monitored. The basis of his adaptation was stated to be the experience of his previous flight.

The cosmonauts gave each other comprehensive medical checks one day every week and on at least one occasion Ryumin, shortly after awaking, had the dynamics of his blood circulation measured while he was still in his bed, in conditions of complete rest. This made it possible to assess the changes in the bodily functions during the adaptation to weightlessness. The crew checked the bio-electric activity of each other's hearts and other functions using the Polinim 2M apparatus. Lyakhov then had a comprehensive examination of his blood circulation, measured to determine the redistribution of blood in his body and the condition of his cardiovascular system. The medical examinations also used encephalograms, oncolograms, reograph, manometer and seismograph apparatus to determine their own physical parameters.

The results of their medical checks were radioed to them from the FCC by Doctor Boris Yegorov, the head of the medical service, who told them that their cardiograms were normal. Lyakhov had lost weight in the first days of the flight, up to 3 kg, although by the end of the first week he had



4. Mission Control, Kaliningrad. On the screen is the ground trace of Salyut 6; left and right, technical features of the space station.
Panorama DDR/Zentralbild

regained 2 kg of that. Ryumin had actually gained 1 kg. Every morning the men measured their weight using the massmeter located on the Salyut's ceiling. The readings were telemetered to the FCC.

Yegorov asked the crew how they were managing without smoking. Lyakhov, a smoker for 28 years, replied that they were managing quite well. They reported that their appetites were "quite fantastic" and that they were sleeping well, from midnight until eight in the morning (Moscow Time). By 7 March the *Protons* had entered a work regime where both of the crew members were permitted to do "physical exercises in full measure". The cosmonauts also wore, as all the previous crews had done, the 'Penguin' suit which, using elastic cords, exerted a pull on various groups of muscles.

In other aspects the cosmonauts experienced niggling problems. They found it difficult to eat with jars, spoons and forks flying about. On another occasion they opened a container full of fruit flies for a biological experiment and allowed several of them to escape into the station's working compartment. The cosmonauts then had to rush about for several minutes catching them. But the sensations of strangeness soon passed.

Settling in

With effect from 28 February the *Protons* entered a working timetable that lasted from 0500 to 2000 for five days a week with Saturday and Sunday off, as had been the procedure for the previous crew. The cosmonauts' only planned activities on these two "days of active rest" were systems monitoring and physical exercises to keep their muscles in trim. "Physical jerks are very important for stressing muscles which are inactive," Ryumin told viewers during a TV broadcast.

They were able to play chess, watch the video monitor with tapes they had brought to the station (after they had linked it to a video monitoring device *via* a small electrical unit they were able to view their own telecasts) and were making use of their cassette library. During conversations with the station the controllers could often hear songs and melodies and on a few occasions the crew beamed the music specifically to the FCC. It took them a while to settle down and read the books in the station's library.

The *Protons* began a number of minor biological experiments soon after settling into their cosmic home. These included studies of the effects of weightlessness on the growth of higher plants and tissue cultures and the fruit flies that had troubled them earlier. They planted green onions in a nutrient solution. Using the flowerpots utilised by the *Photons* to grow onions and other plants the new occupants planted a garden growing cucumbers, an activity described as "more for the soul than science". The crew's farming also included growing onions, dill and parsley to eat.

Assessing the Job

At the end of February Konstantin Feoktistov told reporters that the *Proton's* primary purpose was to act as "experts and appraise the condition of all the systems of the complex". The first of these checks, the docking manoeuvre, had proved that the systems of approach and docking were functioning perfectly. It will be recalled that Salyut orientates itself to the oncoming spacecraft with the docking port to be used facing it, using automatic steering aids.

Earlier crews had only minor repair and installation work to perform involving replacement of such items of lamps and ventilators but the new occupants had to replace entire assemblies and units "to enable the station to operate for a long time yet and ensure the (present) team onboard". Usually basic scientific apparatus is assembled on the Earth in a workshop and carefully checked at a control station. On Salyut 6, for the first time, the activation and testing of new apparatus was done in the station itself. For this task the cosmonauts were provided with a wide selection of repair and installation tools which, in design and use, were specially created for use in space. They included pliers, vices, clamps and screwdrivers, one of which proved to be a spectacular failure when Lyakhov tried to unscrew a panel. *He* turned instead of the screw! Lyakhov soon solved the problem by holding the screwdriver in place, stretching out until his feet touching a wall and pushed as Ryumin turned the screwdriver. For attaching items or units at specific points in the station special bolts and nuts were provided.

The cosmonauts took into orbit with them a "most ordinary fitter's soldering iron" for repairing soldered joints. They used the new tool first to repair the head of the *Vatra* Video-tape recorder which had a life-time of between 200-300 hours. The soldering iron "worked without tin" and special filters gathered up the resulting chips of metal and prevented them getting into scientific apparatus or control panels. New methods had been developed to enable the cosmonauts to connect the VTR head without the help of a microscope, which would have been necessary on Earth.

The *Proton's* programme of preventative maintenance and repair on the station (prior to the launch of Progress 5) entailed them replacing worn cables and other mobile elements, such as switches and headsets, on the radio system "which suffers considerable wear during a long flight". They also installed a stellar tracker, "a new instrument", which they linked to the station's navigation equipment; tested the station's manual control and attitude control systems; examined the hatch opening mechanisms and checked the airtightness of the 'Splav-01' airlock chamber; reloaded and checked the MKF-6M camera; replaced ventilators and changed all of the station's old lamps for new.

The crew made a detailed inventory of all the station's onboard equipment, including the portable items and tools left by the *Photons*, and equipped their work posts which were dotted around the station. There are 7 such work posts: the main control panel, the velo-ergometer, MKF-6M camera, BST-1M telescope and 3 'astroposts' with telescopes including an infra-red inferometer measuring stellar radiation and other devices recording cosmic and solar radiations. One astropost is located in the main work section; the other two are in the forward transfer compartment.

Speaking about their work the flight engineer said that the crew had thoroughly examined the station's interior although they still had not examined the hatches of the 2 docking assemblies and the 3 solar panels. "Moreover these are located outside the station and have been exposed to micrometeorite bombardment, which may have impaired their functioning". Ryumin's words clearly implied an EVA, although Salyut observers did not anticipate one before the Progress 5 launch. The cosmonauts later beamed TV pictures of the station's external elements, seen through a porthole, to the FCC.

Busy as they were the *Protons* still found time to show TV viewers around their station examining the various devices and showing the canteen and shower. They even sent a message to all the women of the world, on 7 March, in honour of International Women's Day which was founded in 1910 by an international women's socialist group to fight for political and social equality. IWD is celebrated on 8 March and is a public holiday in the USSR.

Progress 5

The expected launch of the fifth Progress resupply craft occurred at 0547 on 12 March from the Baikonur Cosmodrome. It was placed into an initial orbit of 191×269 km with a period of 88.8 minutes at 51.6° inclination. The carrier rocket was a standard A-2 minus the aerodynamic spoilers of the launch escape system.

Over the next 2 days the orbit was corrected a total of 5 times on command from the FCC and the tracking ships *Kosmonavt Yuri Gagarin* (45,000 tonnes); *Kosmonavt Vladislav Volkov* (9,000 t); *Kosmonavt Vladimir Komarov* (17,500 t); *Morzhovets* (5,277 t); *Kegostrov* (5,277 t) and *Chazhma* (14,065 t). These ships also helped maintain radio and telemetric contact with the Salyut station.

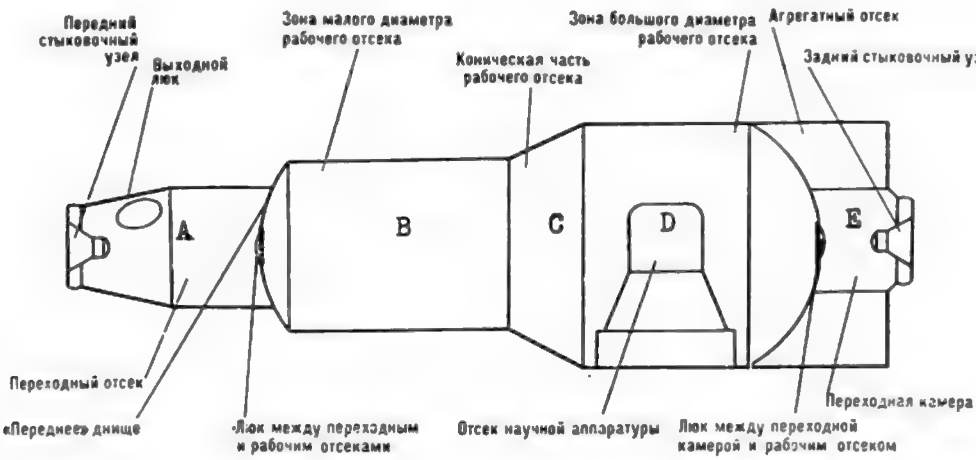
Progress 5 was guided to the point where, once in the 'assembly orbit', the 'IGLA' (Needle) radio navigation equipment system took over. In the words of a Radio Moscow commentator: "finally the illuminated markers on the screen of the FCC drew closer together and the automatic rendezvousing system of the Salyut station took over. Its TV camera sighted the approaching transport and relayed the pictures to FCC .... The docking operation this time was not expected to be easy ... Progress 5 approached from the direction of the Sun, making the work of the crew, who were using optical and TV devices, more difficult. The crew conducted a running commentary on the operation, reporting that they were watching the automatic devices align the approach of the two ships. They said that they could see the craft's beacon light [which was] serving to monitor the alignment. Finally they reported contact and at 330 km altitude the steel grips of the two docking assemblies reliably, with a force of 20 tonnes, linked the two orbital craft together". It was 0720 14 March and the link-up had taken place 4 minutes earlier than planned. The complex was in a 296×324 km orbit.

Progress 5 delivered 2300 kg of cargo, a full load, which comprised 1000 kg of fuel and 1300 kg of dry cargoes including spare parts required for routine maintenance tasks. Specific delivered items included:

LIFE SUPPORT:	Spare systems for regeneration of water from condensate; absorbers; water from the Moscow region "treated with silver ions" for longer preservation.
EQUIPMENT:	6 signalling devices to be located at the work posts to detect "even a minute buildup of carbon dioxide and carbon monoxide, which also serves as a fire warning system based upon the detection of smoke." Even the smoke from a cigarette is enough to trigger it; tape recorder; 'Koltso' (Ring) walkie-talkie system for internal communications between crew-members in different sections of the station; a new "technologically improved" 'Kristall' furnace; sets of film and materials for technological experiments; new 'Stroka' teletype unit "the old one having become unreliable"; replacements for one of the two panels of the command-signal unit, and a reserve storage battery.

5. After their record-breaking flight of 175 days, cosmonauts Valery Ryumin and Vladimir Lyakhov are re-united with their families at the Yuri Gagarin Cosmonaut Training Centre.

Novosti Press Agency



SALYUT 6 ORBITAL LABORATORY. Key: A. Forward docking module; B. Command section with instrument consoles; C. Intermediate section; D. Workshop module with BST-1M telescope; E. Aft docking module. (See also cutaway drawing, *Spaceflight*, April 1979, p. 179).

NUTRITION: Food, in plastic containers: "first course dishes in tubes, second course dishes in jars or special packets". The food was freeze-dried, and prepared using hot water; coffee and tea to last for the duration of the mission; five different types of bread from wheat to rye; fresh vegetables, apples, onions and, at their own request, honey and freeze-dried strawberries.

HYGIENE: The crew received new linen and clothes for both work and exercise; bath shampoo; linen dryer to help with the laundry.

On board the Salyut station at the time of the Progress 5 launch were "practically no renewable resources which were stored there before the station was launched". All of the station's functioning life-support equipment such as regenerators, absorbers and some consumables, as well as scientific equipment had been delivered by the Progress ferries. A Soviet spokesman said that there had been certain deviations noted in the power output from the solar cells, noting that engineers had foreseen this eventuality and catered for it. "The same also applies to the storage batteries (which are re-charged from the solar panels to provide power for the station when in the Earth's shadow). This was remedied by periodic deliveries of additional sections of the (nickel-cadmium) buffer batteries which, when connected to those already in operation, maintain the charge at the required level".

Unloading Progress

Because of the desire of FCC to verify the rigidity and seal of the Salyut/Progress docking interface, the opening of the internal hatches between the two spacecraft was delayed until the next day (15 March). The cosmonauts began that working day somewhat earlier than usual and at 0600 the internal hatch into Progress 5 was opened.

The *Taymyr* crew made a graph of the distribution of the cargoes in Progress before they unloaded it. This is the only instance to date that this activity has been reported and it is unclear whether it is a standard procedure on all such craft prior to unloading.

The first item the *Protons* unloaded was a 9 kg parcel containing letters, newspapers and small gifts from their families and friends. Over the next four days the two men unloaded the cargo craft's 27 containers. In all they had some 300 different items to transfer including containers with foodstuffs, water and life-support systems. They ranged from small parcels to an 80 kg.6 m³ volume regeneration unit and containers with 50 gallons of water.

ODU Problem

The arrival of Progress 5 enabled the Soviets to rectify a problem with one of the three Salyut propellant tanks which had first been spotted at the end of the *Photons*' flight. Soviet engineers noticed deviations in the control parameters in the main pneumatic line of the Combined Engine Installation or ODU (the initials of the Russian name) supercharge system. The Soviets were at pains to stress that the deviations did not affect the overall functioning of the ODU, although it must be noted that from the time of its discovery the problem kept the Soviets from using the ODU for any manoeuvres.

During the period of the station's autonomous flight specialists, studying telemetered information from technical experiments performed automatically, deduced that the cause of the trouble was damage (possibly a hole or perforation) to the membrane separating the liquid fuel and gaseous nitrogen in the tank. When the tank is full the membrane is pushed against the side; and nitrogen is introduced behind the membrane to force fuel out into the main feed lines.

Although the overall functioning of the ODU was not threatened engineers decided that if the problem was not rectified it could lead to unstable functioning of the regulating valves of the fuel system and a wider malfunction of the ODU. They therefore decided to isolate the tank from the main system and switch to the reserve tank (the ODU is able to function on only 2 tanks) transferring in the process the remaining good fuel to the other 2 serviceable tanks. Salyut employs unsymmetrical dimethylhydrazine as fuel and nitrogen tetroxide as oxidizer.

The work plan was developed using a mock-up of the ODU and necessary experiments were carried out on ground test stands.

Early on 16 March the *Protons* switched on the Salyut's manual guidance system and commanded the three-spacecraft complex to revolve slowly around its transverse axis by firing the small attitude control jets. The centrifugal force thus created separated any mixed nitrogen and fuel, which had collected behind the membrane, from the main bulk of the fuel. The usable fuel then was automatically transferred into one of the other Salyut tanks and the residue, a contaminated propellant/gas mixture, was pumped to an empty tank in Progress 5. Then the vent valve was opened to clear the fuel tank and the fuel lines connected with it of the residual fuel. During the orbital operations similar tasks were performed on the ground with the physical analogue of the ODU and a mathematical model of the Salyut.

So concerned with the safe accomplishment of the task were the FCC controllers that they assumed absolute control, during periods of radio-visibility, for all major events, such as pumping and other critical operations. There appear to have been some "heated exchanges" during the operation between the FCC and the cosmonauts, probably a sign of the nervousness with which the operation was viewed. The successful accomplishment of the operation was proof of the increasing maturity the Soviets are showing in their manned flights, a maturity first illustrated by the ease with which the original Soyuz 25 flight plan was performed by the Soyuz 26 crew after the earlier mission had failed.

The thrusters of the Progress ship were fired to stop the rotation and the FCC, over the next 7 days "rinsed the tank," and the main line by leaving it exposed, *via* the vent valve, to open space using daily blasts of nitrogen from the compressor. At the end of this period, on 23 March, the valves were closed following one final burst of nitrogen. Four days later the tank was filled with compressed nitrogen and disconnected from the fuel system. Two days later the oxidizer tanks were prepared for refuelling.

Ryumin, who had contributed to the design of the ODU, recalled the methods of constructing the ODU and the difficulties which arose before problems were solved; the practical solutions (of the refuelling) turned out to be quite difficult. In 1974 a book, published in the USA, claimed that as early as 1969 the USSR had demonstrated fuel transfer between two connected tanks on an unmanned Cosmos flight (this experiment was unannounced)[3].

Installation of Equipment

The *Protons* installed and checked, generally ahead of the timeline, many new items and pieces of equipment replacing those that had exceeded their planned working lives. A major item of equipment the crew installed was a new command the signalling unit which the Soviets say is capable of handling over 100 commands such as switching to manual orientation, selection of engines and communications. Tests confirmed that it was operating correctly.

The crew installed a new clock, replaced a scientific instrumentation control panel, plugged in a set of additional storage batteries "to restore the parameters of the control system," moved the sextant from one porthole to another, installed and tested the '*Koltso*' (Ring) communications receivers and transmitters. In addition to providing for internal communications

the *Koltso* system enabled the crew to communicate directly with FCC and allowed greater freedom of movement within the station. The men also installed the *Yelena* gamma telescope in the station's scientific equipment compartment. They dismantled the Kristall furnace, located in the transfer compartment, which had been used for over 40 smelting experiments since being delivered by Progress 2 and replaced it with a new, improved, Kristall unit.

Earth - Orbit TV

From the beginning of manned operations in Earth orbit Soviet TV viewers were used to seeing daily telecasts from the cosmonauts in Salyut 6. For the two men aboard, however, there were now facilities provided for them to see the events on the Earth *via* a B/W TV delivered by Progress 5. The cosmonauts assembled, together with its receiving antenna, the compact TV set and checked its operation.

At the FCC the telecommunications operator, whose job it is to converse with the crew and who is a cosmonaut himself, was shifted to allow two cameras to view him. One camera was looking at him while the other was aimed at his work console.

Television transmissions on the "Earth-Orbit" link began on 24 March and were conducted simultaneously over 2 telecommunications sessions. The first thing the cosmonauts saw was a poster which bore the legend "The First Telecast From Earth To Orbit". During the TV show the crew saw pages of that day's *Pravda*, drawings from the on-board manual and a short film of their launch on 25 February. The received image was, they said, clear and steady. Later the *Protons* held conversations with, and were able to see at the same time, Flight Director Aleksei Yeliseyev and cosmonaut Valeri Kubasov (who is expected to command one of the international flights) who were located in one of the Science Support Rooms adjacent to the FCC.

The implications of the new facility were soon being lauded by Soviet commentators who noted that texts, graphs, drawings, photographs, instructions from scientific personnel, film of training sessions and even daily Central TV from Moscow, could be beamed to the crew. The unnamed Chief Designer of the TV project said that the facility would enable the cosmonauts to link-up directly with large computer systems. "We have the TV screen and ... the corresponding control panel on board the Salyut and the cosmonauts can call up information from the Earth, which will be processed by large computers. The possibilities are ... really unlimited".

Another Soviet commentator said "it is difficult to overstate the significance of the experiment for the development of manned flights ... one should not forget the tremendous psychological support the cosmonauts will receive from meetings, *via* TV, with their relatives and friends. All of this will give the crew ... a feeling of ... close links with the Earth (helping) them to fulfil the flight plan successfully".

The cosmonauts took time off from resting one day in April to tell TV viewers about their schedule on rest days. Lyakhov said that it began at 0800 (MT) with "physical jerks and exercises and breakfast, as on working days ... At this time we have music. We have an Elektronika cassette recorder and 64 cassettes for it. Then we service the station. On our rest days we observe the surface of the Earth, photographing the most interesting subjects and making a brief note of our impressions in our ship's log or record a commentary on the cassette recorder ... (From) 1200-1300 (MT) ... (we do) physical exercises on the training apparatus. In the evening we watch the videotape. We have about 50 video cassettes in our library with films, concerts and cartoons".

In addition the crew had their shower cubicle. The *Protons* used it for the first time on their flight on 23 March. Earlier they had installed a new "curtain" or "elastic shell" on the unit and to avoid a problem that had plagued the two earlier crews, soap getting into their eyes and ears – the *Protons* were issued with scuba diving masks. To stop water from clinging to the shower cubicle the crew brought a new instrument to the station, a ring with holes in it that slid along the inside of the shower to collect stray water. Although earlier crews had been less than impressed with the shower the *Protons* reported that they had thoroughly enjoyed it.

For sleeping the crew had two sleeping bags, one fixed to a wall and the other to the ceiling.

Undocking of Progress 5

Following completion of the unloading and installation of the equipment delivered by the Progress 5 transport the *Protons* began transferring used equipment, such as regenerators, absorbers, empty water and food containers into the cargo compartment of the unmanned cargo ship.

Before its work was completed and it was detached from Salyut 6 to plunge to destruction over the Pacific Ocean away from shipping lanes, the Progress 5 was used to twice raise the orbit of the complex. One manoeuvre on 30 March brought the station complex up to an orbit of 284 × 357 km × 90.6 minutes; the second on 2 April, took it to its nominal 91.4 minute orbit. Following the first manoeuvre the station's propulsion system was topped up with oxidizer under the joint control of the crew and the FCC specialists.

The next day 3 April, at 1610, Progress 5 was commanded to undock from the Salyut 6/Soyuz 32 complex after a joint flight with the complex lasting 21 days. During its 2 days of autonomous flight an (undetailed) radio homing experiment was conducted. On 5 April the unmanned cargo spacecraft was commanded to fire its engines and enter the atmosphere where it was destroyed in the atmosphere.

The next major event was expected to be the launch of the fourth international crew to the station, following the successful flights of the Czechoslovakian, Polish and German cosmonauts during 1979. The Soviets said that cosmonauts from Bulgaria, Hungary, Cuba, Mongolia and Rumania were training in Star City for flights in Soviet spaceships. The first crewmember from this group to fly was to be a Bulgarian. The selection of a Bulgarian was being explicitly stated as early as 26 February when the Bulgarian daily *Rabotnichesko Delo* had said that the repairs being done to the Salyut 6 station by the *Protons* brought closer the "starting stage for the forthcoming penetration of space by a Bulgarian citizen." Later, on 17 March, the Bulgarian press agency BTA said that "much is expected from the work of the first Bulgaro-Soviet crew of the Soyuz which is to fly in space in a short period of time."

As the cosmonauts aboard the Salyut 6 complex began work on their main flight programme which envisaged research into the Earth's natural resources, the atmosphere, stellar processes, biological and medical research and materials processing in weightlessness, they gave the orbit of the complex a final "trim" on 6 April using the Soyuz 32 engines. On the 9th, Moscow reported that the crew had officially begun work on the main flight programme.

To mark the beginning of this programme the Soyuz 33 spaceship was launched on 10 April.

Soyuz 33 Crewmembers

As the cosmonauts were settling into their planned long flight aboard the Salyut 6 space station the first InterKosmos crew were preparing for their flight to the station to work on it for a week and return in the Soyuz 32 spacecraft. Crewmembers

* *An earlier version of the poster ended with the words "in the history of the universe", but this sentence was omitted when researchers pointed out that none could supply undeniable proof that there were no other extraterrestrial civilisations that may know of, or use TV.*

of the fourth InterKosmos crew were Soviet commander Nikolai Rukavishnikov, a civilian, and Bulgarian Air Force Major Georgi Ivanov. While the commander was a well known figure prior to the flight and his crewmate attracted all of the attention from the media, it must be noted that Rukavishnikov was the first civilian ever to command a Soviet manned spaceflight. When Rukavishnikov was named, on 4 March 1978, as the reserve commander of the Soviet/Czechoslovakian Soyuz 28 flight, there were those amongst Salyut observers who doubted that the Soviets would ever allow a civilian to command a manned flight [4, 5].

Shortly before leaving for the Baikonur cosmodrome for their launch Rukavishnikov said that the *Saturns* (their call sign) were waiting "with great emotion for the launch and docking." Bulgarian specialists had prepared 28 joint experiments in the fields of space physics, space technology, biology, medicine and remote sensing of the Earth. Some of the experiments were delivered to the Salyut 6 in the Progress 5 cargo spacecraft. The *Saturns* were scheduled to work for one week aboard the Salyut. One of their experiments, called Spektr 15k, had as its objective a spectroscopic survey of the Earth "for the first time in space."

Rukavishnikov confided in a TASS interview that they had prepared a couple of surprises for the *Protons*. "Georgi has a very special surprise, never before seen in space;" although the commander did not reveal what the surprise was he did note that "we must not forget that a reverse television link can now be established."

Launch of Soyuz 33

Cosmonauts Rukavishnikov and Ivanov, after their arrival at the launching pad late on 10 April, local time, gave short speeches. Rukavishnikov said that he was happy to be flying into space with Ivanov with whom he would conduct joint experiments. They boarded the carrier rocket just over 2 hours before the scheduled launch time. It was windy, with gusts up to 18 km/hr, prompting Rukavishnikov to tell Ivanov that he should "consider this as a rehearsal for weightlessness."

A Bulgarian delegation was at the launching site to see their representative off. It comprised Dorbi Dzhurov, member of the Politburo of the Bulgarian Communist Party Central Committee; Angel K. Serafimov, Chairman of the InterKosmos Council of the Bulgarian Academy of Sciences and Stoyan Mikhaylov, Secretary of the Bulgarian Communist Party Central Committee.

Once in the re-entry capsule of Soyuz 33 they checked the hermeticity of the compartments and its systems. B/W TV showed the crew in the cabin, with a small white doll dangling between them on an elastic thread. Rukavishnikov introduced the mascot as "our third crewmember ... upon whom Georgi is to conduct a number of experiments in weightlessness." In Space Vladimir Lyakhov and Valeri Ryumin, who had adopted a time table for the docking, said they were looking forward to the arrival of the InterKosmos crew.

As launch time approached the wind had increased with some gusts registering speeds of 40 km/hr. A Soviet report said that they were the worst conditions ever for a Soviet manned launch. Finally, at 17:34:33, the command "start" was given. The engines built up power and lifted the rocket into the air. 18 years previously, almost to the day, Yuri Gagarin called out "in a calm, almost nonchalant voice: *'poiekhali'* (let's go!) ... Now Nikolai Rukavishnikov and Georgi Ivanov called out these same words, with the same calm."

During the launch phase Ivanov's pulse rate was almost stable, between 72-74 beats/min., prompting Georgi Grechko to say that Ivanov may well turn out to be the calmest cosmonaut in the history of the InterKosmos programme.

In just 10 minutes the spacecraft had left the high winds, and all other earthly processes, behind and was in orbit; soon the cosmonauts left the night time in which they had begun the flight and saw their first orbital sunrise over the Far East. Towards the end of their first orbit, in darkness again, the men established communications with the FCC *via* the research ship *Kosmonavt Vladislav Volkov* anchored off the coast of Africa.

At the FCC two groups of flight controllers were working simultaneously. One group tracked Soyuz 33 while the other monitored the Salyut 6/Soyuz 32 complex. During their second orbit the *Saturns* checked the approach and rendezvous systems. These systems checks lasted for the first three orbits during which the crew kept their space suits on. Following the safe completion of these checks they doffed the suits, opened the hatch of the Orbital Compartment and prepared for supper. They were given information about the orbital corrections which were scheduled to be carried out on the 4th and 5th orbits [6]. The correction engines were activated during these orbits putting Soyuz 33 into an orbit "closer to that of Salyut 6." At 0100 (11 April) the *Saturns* turned in for some well deserved rest. Their second working day was scheduled to begin at 1300. A Soviet report said that the docking was to occur "before" 2100 on the 11th (a more accurate estimate based upon previous launch/docking time differences indicates that docking was planned for about 1915).

Bulgarian Reactions to the Flight

The Bulgarian mass media was soon lauding the flight claiming that the launch put Bulgaria to the status of the world's 6th spacefaring nation. They also gathered reactions to the flight from various people who knew Ivanov and figures in the arts and sciences [7].

Ivanov's mother wished her son great success, and his father noted that the family "had known for a long time that Georgi was getting ready for a spaceflight ... The announcement of the launch ... was still a shock." He expressed his confidence in the crew and their ability to perform the required tasks "because (he) is flying aboard a Soviet spaceship commanded by an experienced Soviet cosmonaut ... His mother and I are eagerly awaiting the reports of the docking of the Soyuz 33 with the orbital station."

Bulgarian leaders expressed their thanks to the Soviet government for "sharing (with us) its enormous scientific and technical experience ... in the exploration of the universe."

Bulgaria's oldest living (100 years young) communist expressed his joy at the news noting that "if I were younger I would embrace him and wish him well." A Bulgarian had even composed a song for the event.

In the Bulgarian capital, Sofia, and Ivanov's home town, Lovech, the next morning "emotional mass rallies were held to acclaim the flight." The rally in Sofia was attended by Soviet cosmonaut Pavel Popovitch who, in a speech, told the watching Bulgarian citizens that other Bulgarians would fly into space "in the not too distant future." Popovitch stressed the importance the Soviets attached to the InterKosmos programme.

Docking Problems

By 1300 11 April Soyuz 33 had completed 13 orbits. Following the manoeuvres the previous night the spacecraft was in an orbit with the parameters of: height 273 to 330 km; period 90.1 minutes. The crew reported that all of the ship's systems were working and the approach was progressing normally.

By 1830 the Soyuz was completing its 17th orbit and had made 5 orbit corrections to arrive at that point in space. At the FCC scarlet and pale blue lights, representing Soyuz 33 and the Salyut 6/Soyuz 32 complex, on the display screen were drawing closer together. The FCC was now able to hold conversations with both crews simultaneously as they entered the same communications zone.

Flight commander Aleksei Yeliseyev sent final instructions and the telecommunications operator read up calculations for the final manoeuvres before the rendezvous. Docking was scheduled for the next orbit. The distance between the two

spacecraft was now about 3 km, Rukavishnikov later said that at this point all of the systems were working normally. But, at 1854, when the approach was commanded and the time came to activate the engine for the approach to the Salyut, to slow the lateral velocity, Rukavishnikov, and engineers at the FCC *via* telemetry, noticed "deviations in the regular operating mode of the approach-correcting propulsion unit of the Soyuz 33 engine." "We noticed something wrong with the engine's function," Rukavishnikov later said.

The atmosphere at the FCC tensed as engineers sought, from the telemetered data, to isolate the fault. In space the crew had no way of diagnosing the fault on board as the spacecraft contained few readouts on the engine function (the duration of engine burns is controlled by the FCC with the crewmen timing ignition and shutdown on a stopwatch and reporting that to the controllers). The problem was all the more acute as a fault with the engines might affect the crew's ability to return to the Earth. Despite the problem the two cosmonauts expressed their willingness, and desire, to continue the flight using hand operations and the reserve engines for the approach. The FCC specialists however adhered to the "ironclad law" to safeguard the life and health of the cosmonauts (it must be remembered that the Soyuz 33 was to be left in orbit for use by one of the later crews) and aborted the docking operation, instructing the crew to return to Earth as specified using the alternative flight plan.

The *Saturns* reportedly acted coolly and calmly to the events although they were later to admit to a certain amount of bitterness about cancellation of the docking. Their most vital tasks now were to prepare for the descent which would be under emergency conditions in the western landing site near Dzhezkazgan on the first available opportunity. Their descent, as had those of the Soyuz 29 and 31 ships, would take them over the Baikonur cosmodrome instead of the more used eastern site near Tselinograd. That event for the *Saturn* crew was still some 21 hours away. During the remaining time in orbit they conducted some Earth observations, slept and ate. Earlier Soyuz vehicles have been powered down to conserve electrical energy (the ferry Soyuz has only a 2½ day battery power supply) following docking failures.

If electrical power was short then the one thing the cosmonauts had in abundance was advice. Before their final orbit the next day (12 April, Cosmonautics Day in the USSR) Vladimir Shatalov, using his call sign *Granit* (the FCC call sign is *Zarya* meaning Dawn), spoke to them over the radio. He told them of his confidence in them and in the equipment although he gave the option of overriding any of the preprogrammed sequence of events if they deemed it necessary and advised them that there were sufficient recovery teams around the landing site to meet them quickly, reminding them that the area where they would touch down was not highly populated and was dotted with "sparse small shrubs." Shatalov told them that as the touchdown would be at night they were to turn on their beacon "and all other means" to attract the attention of the recovery helicopters. Rukavishnikov replied that the crew were prepared and were confident of success. Finally Shatalov told Rukavishnikov to ensure that Ivanov's large bushy moustache was safely tucked inside the visor of his helmet before sealing it! The comment provided a moment of light relief before the difficult reentry.

Landing of Soyuz 33

From US data it appears that during a normal reentry sequence after separation from the Salyut laboratory a Soyuz makes two manoeuvres, the first achieving a low orbit, the other the reentry proper. It must be stressed that the Soviets, or the InterKosmos countries, do not report the first manoeuvre, if indeed it occurs. With Soyuz 33 only one manoeuvre was performed, dictating a steep, uncontrolled ballistic reentry. On its 27th orbit, about four orbits prior to the reentry, Soyuz 33 was tracked by western sensors in a 298 × 346 km orbit, reportedly higher than the normal attitude for retrofire.

After donning their spacesuits and verifying the hermeticity of the landing capsule the cosmonauts oriented the Soyuz, using the Earth's horizon as their reference and then held the spacecraft in that attitude until the reserve, 411 kgf thrust, engine was fired over the South Atlantic on a command from an on-board timer, monitored by the research ship "*Borovichi*" (5,276 tonnes) anchored under the flight path. The engine fired successfully for 213 seconds. Following the shutdown of the engine, with the Soyuz now in a descent trajectory, the Orbital and Service modules separated from the Descent module containing the crewmen.

A ballistic descent is uncontrolled and dictated by the laws of gravity as distinct from the normal "lifting reentry" which is shallower and reduces overloads on the crewmen. During the 530 seconds of their descent the *Saturns* experienced between 8 to 10 g's, compared with 3 to 4 g's for a normal reentry. This meant that at one stage Rukavishnikov weighed 10 times his normal 75 kg. Although in such conditions even breathing is difficult the crew were heard talking to each other. Ivanov later said that he felt the load factor for several minutes. Outside the cabin the temperature reached 3000°C. giving Rukavishnikov the impression of having been thrust inside the flame of a blow torch. He later reported that a lot of noise and vibration accompanied the descent. At the FCC there were "many minutes of tension" as the heat ionized shell surrounding the spacecraft cut off communications.

From out of a cloudless sky, under a full Moon, the capsule, still red hot, was seen by a pilot of one of the recovery aircraft. The sight was later described as a brilliant light which approached at about one degree above the horizon. Soon the capsule cooled and the light faded. The cosmonauts were soon in contact with the recovery forces and were reporting that they were feeling well and that the main parachute had deployed. At 1635, in a cloud of dust blown up by the soft-landing motors, the capsule settled down on the ground, some 320 km south east of Dzhezkazgan, just 15 km away from the target area. A recovery aircraft was quickly circling overhead and the pilot, spotting the beacon light, pinpointed the position to the helicopters. When the helicopters arrived they found the Soyuz capsule had rolled onto its side (a common occurence) [8]. The cosmonants had opened the hatch and were standing beside it waving. There followed some emotional greetings from their comrades. Physicians soon arrived at the landing site and, following a brief medical examination, pronounced the crew to be in good health.

Deputy flight director Viktor Blagov, at the FCC, praised the crew's work and reactions during the Soviet Union's "second successful ballistic reentry" and noted that they went "about their tasks after (the problem) and the way they performed them has earned them the trust and respect of all my colleagues . . . (the flight) has been the most complicated one we have ever had." Soviet media reports were soon stressing the benefits the engineers were to reap from the study of the flight. The engineers would have to use the telemetry returned from the Soyuz during the flight to diagnose the flight problems as the engine system which malfunctioned was destroyed in the atmosphere following separation from the other two sections of the Soyuz 33 spacecraft [9].

A cable to the crew from Bulgarian State Leader Todor Zhivkov praised their "high competence and skill, exceptional courage, strong willpower and heroism during the complications which interupted their honorary and difficult assignment."

Return to Baikonur

The two cosmonauts were soon returned by air to the Baikonur cosmodrome for further intensive medical checks and de-briefing reports. There they were greeted by specialists in "sunny spring weather" which provided a marked contrast to the strong winds during their launch just three days earlier.

During their first day at the cosmodrome (13 April) they were allowed to take a short walk around the Hotel Kosmonavt from where they had departed for the launching pad. To commemorate the flight they planted Bulgarian red roses in the hotel's garden. Rukavishnikov remarked that although they had been away from the Earth for just 2 days they felt "as though we had been working in space for a whole month."

Soviet medical specialists noted that many other cosmonauts had described the same sensations "which can by no means be called subjective. "During the most crucial periods of work in orbit man gets the impression that each 90 minute period is equivalent in terms of the intensity of events and emotional load to a full 24 hours," veteran cosmonaut Aleksei Leonov told reporters.

At a press conference held in a "casual, unaffected atmosphere" at the hotel, in an introduction, the crew were said to have shown "an exceptional precision, composure and courage ... and a profound professional knowledge of the systems (of Soyuz). The cosmonauts told the assembled reporters that following extensive medical examinations, including an aortal test, and performing physical exercises, they were feeling "quite well." The press conference was attended by the cosmonauts' physicians.

In his description of the flight Rukavishnikov said that "machinery is only machinery; things can go wrong. During the flight we had serious remarks to make on the functioning of the engines during the approach to Salyut. These reports forced the FCC to stop the mode of the flight ... (to have proceeded) would not have been without danger."

Bulgarian scientists noted that the problems encountered during the flight demonstrated that "the point is not yet reached when scientists will be able to fly in space ... Although there is still no analysis of the failure of the manoeuvring engine there is a chance that there may have been a meteorite clash. The engine has been tested for thousands of hours on the ground. The flight will probably rank along with the Apollo 13 crew's experience although they were in a more difficult situation indeed."

After their completion of post flight medicals and debriefing the crew arrived, on 23 April, at Zvezdyy Gorodok (Star City) near Moscow where the cosmonauts live. In their speeches Rukavishnikov stressed the benefits of space flight for the economy and Ivanov said that he was "proud of the part my small Bulgaria plays ... in the InterKosmos programme."

Awards for the Crews

The prime and reserve crews of the Soyuz 33 were awarded several State and National titles on 14 April. These included for Bulgarian cosmonauts Ivanov and Aleksandrov the titles "Cosmonaut flyer of the Bulgarian Peoples Republic," "Hero of the Soviet Union," "Hero of the People's Republic of Bulgaria," and Gold Star medals of the USSR. In addition Ivanov was promoted to Lt-Col Engineer, Aleksandrov to Captain Engineer.

Soviet cosmonauts Rukavishnikov and Romanenko were awarded the title "Hero of the People's Republic of Bulgaria" for their "active participation in preparations for the Soviet-Bulgarian spaceflight and services rendered for the cause of Soviet-Bulgarian friendship." In addition Rukavishnikov was awarded an Order of Lenin by the Soviet government to add to his two "Hero of the Soviet Union" awards.

Presenting the awards in Moscow on 3 May President Leonid Brezhnev told the cosmonauts that their flight would be given prominence in textbooks dealing with the exploration of space. The crew, Brezhnev said, had worked in unusually difficult conditions and he admired the self control, courage and professional skill that the two men had displayed.

To be continued.

NOTES TO MAIN TEXT

1. An article contained in the January 1979 issue of *Sputnik* (a condensed version of an earlier article in *Izvestia*) revealed that the Progress 4 cargo spacecraft was to have changed the atmosphere of the station. It was believed that the chemical composition of the air, despite being specially filtered, had changed extensively. However, analysis of air samples returned by Bykovski and Jähn revealed no chemical, biological or bacteriological changes to the atmosphere's composition, so the task was deleted. The Soyuz 24 cosmonauts aboard the "military" Salyut 5 station had changed the atmosphere of that station by bleeding the station's air out into space *via* a vent valve as air was pumped into the station from bottled supplies on the Soyuz ferry.

2. The civilian space stations Salyuts 4 and 6 operate in an orbit with a period of 91.4 minutes which provides repetitive ground tracks over the same areas of the Earth every 31 orbits, or every 2 days less 48 minutes (J. E. Oberg *Technical Note* dated 21 November 1975).

3. Robert N. James, *Soviet Conquest From Space*, Arlington House Publishers, Washington, 1974. The same book described the Soviet long range plans for a reusable shuttle-type vehicle and an orbit-to-orbit tug which have since shown signs of being developed by the Soviets. It is a quite remarkable book.

4. These periodic switches of Soyuz spacecraft are necessary because the Soviets apparently discovered during the 91 day 21 hour 52 minute flight of Soyuz 20 that serious systems degredation had occurred in some of the vital areas of the spacecraft (which was unmanned). The Soviets now consider it prudent to switch spacecraft rather than have the systems of one threatened for a period longer than 91 days. Soyuz 20 was launched on 17 November 1975, docked automatically with Salyut 4 on 19 November and returned to Earth on 16 February 1976. A new variety of gladiolus which was bred from bulbs of the Dixieland variety aboard the Soyuz 20 spaceship during the flight has been named after the spaceship.

5. Including the compiler! Rukavishnikov may also be entitled to lay claim to being the first true civilian commander of any spaceship. Neil Armstrong the USA's only civilian commander was a Navy aviator and a NASA test pilot before becoming an astronaut with civilian status.

6. On previous flight the first correction, to iron out any launch vehicle errors, has a ΔV of about 5-6 metres per second and the second, the first true manoeuvre into the rendezvous orbit, has a ΔV of about 36 metres per second.

7. During the InterKosmos flights coverage of the activities is left almost totally to the participating country's news media with Soviet reports covering only the basic details, as they do for their basic day-to-day reporting of their domestic flights. Another interesting point that emerged during the Polish flight was the fact that the InterKosmos crew was not allowed to interfere with the daily routine of the resident Soviet crew, to the extent that on a rest day for the Soviet crew the InterKosmos crew did their experiments in the Soyuz Orbital module.

8. The occurrence is so common that at one time it was thought that the Soviets deliberately turned the craft on its side to facilitate egress for the crew.

Salyut 6 Mission Report/contd.

9. The first successful ballistic reentry appears to have taken place during the Soyuz 18A "5 April (1975) Anomoly" when the launch vehicle carrying cosmonauts Lazarev and Makarov developed faults in the separation devices of the core and upper stages. The spaceflight-to-be does not find its place among the Soviet manned spaceflight tables these days. A US report has also attributed a ballistic reentry to the Soyuz 24 flight which landed at 0936 GMT on 25 February 1977.

Acknowledgements:

Sources used in the compilation of this report were (in alphabetical order): *Aviation Week and Space Technology, Aviatsiya i Kosmonavtika, BBC Summary of World Broadcasts (Section D), Flight International, Izvestiya, Kraznaya Zvedzda, Letectvi i Kosmonautika, Moscow News, Moscow News Information, Pravda, Rabotnichesko Delo, Soviet News, Soviet Weekly, Zemlya i Vselnaya.* In addition materials made available by the Novosti Press Agency and the author's own monitoring of Daily Short Wave broadcasts in English by Radio Moscow World Service and to North America and Radio Sofia to Europe and North America proved invaluable.

DAILY LOG OF ACTIVITIES ABOARD SALYUT 6

This day to day listing of major activities of crewmen on the Salyut 6 space station and the Soyuz flights associated with it was compiled from reports on the flight carried in the BBC *Summary of World Broadcasts, Pravda, Izvestiya, Novosti* Press Releases, *Soviet News* and the compiler's own monitoring of daily short wave broadcasts by Radio Moscow, Radio Sofia and the Voice of America.

Date	Scientific Observations	Medical Observations	Mission Milestones, Ship's Systems and Technological Experiments
		February	
25			Soyuz 32 launched at 1154. Crew V. Lyakhov and V. Ryumin.
26			Soyuz 32 docks with Salyut 6 at 1330. Crew mothball Soyuz 32 systems and enter Salyut.
27		Work day lasts from 0700-2000. First medical results show the crew are adapting to weightlessness normally and are maintaining a high degree of efficiency.	Reactivation of Salyut systems switching on water, air and electricity. Temperature of station's living compartments is 20°C. Pressure 770 mm.
28		Working day stabilises to 0500 to 2000 for rest of flight. Experiments begun to observe the development of plants and tissue cultures delivered by Soyuz 32. Crew daily measure their bodily masses.	Crew activate heat control, water regeneration and ventilation systems.
March 1	Crew photograph station's 20 portholes to evaluate erosion.		Crew test efficiency of the Salyut's control system in manual mode. Orbit of the complex is raised by 35 km by Soyuz 32 engines.
2		First of weekly series of medical checks. Crew have adapted to weightlessness.	Crew continue reactivation and checking of station.
3		Day of "active rest". Crew do physical exercises.	Crew clean interior of the station.
4	Crew's first opportunity to view the Earth; "so far they have been too busy."	Continuation of biological experiments on day of active rest.	Checked control panels with scientific apparatus. Changed station's lamps.
5	MKF-6M camera reloaded and checked.	Biological experiments continued.	Prophylactic examination and control of scientific equipment. Repaired VTR with soldering iron.
6		Crew do physical exercises and continue biological experiments.	Checked Salyut's radiotechnical systems.
7			Salyut put into gravity gradient stabilized mode "so that Earth can be viewed from all sides without fuel wastage."
8		Radioed greetings to women on IWD. Spoke to family and friends.	Crew check airtightness of Salyut's cargo containers.
9	Reported eruption of volcano on White Island, New Zealand.	Biological experiments continued.	Conducting repair and maintenance. "There are up to 50 communications sessions with the station daily."
10		Day of "active rest." Did physical exercises.	

11		Day of "active rest." Spoke to family and friends.	
12			Launch of Progress 5 at 0547.
13			Preparations for docking of Progress 5.
14 15 16			Progress 5 docks at 0720. Crew begin unloading Progress. Station put into spin to separate contaminated fuel (see main text). Preparing ODU for refuelling and unloading the cargo spacecraft.
17		Day of active rest. Did physical exercises.	Conducted minor repairs, installed new command and signalling unit (CSU) and other equipment at their own request.
18		Day of "active rest."	
19		Physical exercises, monitoring biological experiments.	Completed unloading of Progress 5. Dismantling units from Progress and stowing and installing equipment. Tested CSU.
20			Adjusted portable TV camera; returned TV of station's exterior *via* a porthole.
21	Transmitted TV panoramas of land and sea surface sections. Recorded meteorological processes in Earth's atmosphere.		
22	Visual observations of density and pollution of upper atmosphere.	Crew continue to feel well.	Loading Progress 5 with discarded equipment. First metals smelting experiment conducted in new Kristall unit.
23		Continuing biological experiments with higher plants and a tissue culture. Crew took a shower in afternoon.	Continued regular repair and maintenance of ODU.
24 25	Visual observations of Earth.	Day of active rest. Did physical exercises. Day of active rest.	First TV transmissions on "Earth to orbit line". First Soviet/French metals smelting experiment begun in Kristall growing crystals.
26		Day of medical checks. Lyakhov's pulse 60 beats/min, blood pressure 115/72; Ryumin 55 and 105/70. "Fulfillment of programme (continues) more reliably and stably with every passing day."	
27		Continuing physical exercises.	Conducted 2nd Soviet/French smelting experiment. Repair and maintenance of fuel tank completed.
28		Conducting biological research on higher plant species subjected to artificial gravitation.	2nd Soviet/French smelting experiment completed. Installed and tested *Koltso* walkie-talkie system.
29			Continued unpacking
30	Observations with *Yelena* gamma ray telescope continued.	Observing development of plants and doing physical exercises.	Correction to orbit using Progress 5 engines. Crew loading Progress with used equipment. ODU "topped up" with oxidizer.
31		Day of active rest, spoke to family and friends.	"Crew have practically completed all repair and maintenance measures."
April 1	Visual observations of Earth studying land and sea areas.		Performed sanitary and hygienic measures. Soviet/French smelting experiment conducted.
2		Crew measure their body masses and volume of muscles with a slight load. Cardiovascular measurements made.	Crew complete loading Progress 5 with used materials. Correction to orbit using Progress engines puts the Salyut 6 complex into nominal rendezvous orbit. Temperature 20°C.; pressure 770 mm.
3			Progress 5 separated at 1610.
4	Crew check BST-1M and calibrate UV channel. Measured UV emissions of several stars to ascertain their relative brightness.		Progress 5 continues autonomous flight.

5	BST-1M observations of upper atmosphere.	Continued biological studies.	Progress 5 destroyed in the atmosphere.
6	Photographed Earth's cloud cover and ocean currents.	Crew have medical check-ups. "They keep asking FCC to increase their workload. They have fully adapted to weightlessness."	Orbit "trim" using Soyuz 32 engines. Soviet/French smelting experiment completed.
7		Day of active rest.	Soviet/French smelting experiment concluded.
8	Recorded results of experiments into their diaries. Visual observations of Earth's surface.	2nd day of active rest. Did physical exercises.	Soviet/French smelting experiment concluded.
9	Crew begin work on main research programme.	Day of medical tests.	By 0900 Salyut 6 has completed 8800 orbits. Two TV transmissions on "Earth to orbit line" scheduled.
10		Crew standing up well to flight showing a high capacity for work.	Soyuz 33 launched at 1734. Crew N. Rukavishnikov (USSR) G. Ivanov (Bulgaria).
11			Soyuz 33 docking cancelled. Salyut crew smelt metals.
12			Soyuz 33 lands at 1635. Salyut crew continues metal smelting.
13		Physical exercises conducted.	Salyut put into gravity stabilised mode for start of 1st "Splav-01" smelting experiment. Crew serviced station and controlled equipment. Temperature 22°; pressure 770 mm.
14	Visual observations of Earth's land and sea surfaces.	Day of active rest. Did physical exercises. Continuation of biological experiments using "biogravstat."	Conducted technological experiment in Kristall unit. Obtained antimonide of indium.
15	Visual observations of Earth's land and sea surfaces.	Day of "active rest."	Conducted technological experiment in Kristall unit. Obtained monocrystal of germanium.
16	Took photographs of European part of USSR to determine the snow melting rate and soil moisture content.		Carried out control checks of onboard systems. Worked on scientific equipment and prepared documentation.
17	Continued visual observations programme of the Earth.	Measured body masses (Lyakhov lost 1.5 kg; Ryumin remained stable). Evaluated conditions of muscles not subjected to stress in weightlessness.	Inspected station's compartments; prepared scientific equipment. Conducted technological experiment on the Kristall unit.
18	Continued visual observations of Earth's surface.	Monitored biological experiments. Performed physical exercises.	Technological experiment on Kristall unit obtained a monocrystal semiconductor material – indium antimonide.
19	Studied dynamics of ocean currents and behaviour of fish shoals.	Day of medical examinations. Biological experiments studied, dynamics of gas composition in closed environment. Continued monitoring biological experiments.	Monocrystal of germanium semiconductor obtained on Kristall unit.
20	Continued visual observations of Earth's surface.	"Crew's cardiograms are normal." Crew in "good frame of mind."	
21		Day of "active rest."	Jettisoned containers of rubbish into space.
22		Day of "active rest".	Experiment in space materials study conducted on Kristall.
23	Photography of Earth continued.	Pulse rates: Lyakhov 56 beats/minute, Ryumin 57. Blood pressure 135/60 and 120/60 respectively.	
24	Noted progress of North African cyclone. Meteorological processes over USSR studied.		
25	Observations and photography of land and sea surfaces. Studied atmospheric weather phenomena.	Crew maintain a good capacity for work and keep in good health.	
26	Studied Earth's natural resources and environment by visual and photographic surveys of Earth.		60th day of flight; over 950 manned orbits completed.

27		Studied reaction of cardiovascular system to simulated hydrostatic pressure using the *Chibis* vacuum suit.	Final Soviet/French smelting experiment conducted.
28		Day of active rest.	
29	Continued visual observations of Earth's surface.	Day of active rest. Sent greetings message on occasion of "World Twin Cities Day".	Worked on shower installation.
30	Visual observations of Earth's surface. Photographed Baikal, Caspian Sea, Kazakhstan, Caucusas and Volga Delta areas of USSR.	Further cycle of experiments conducted with "biogravstat".	

THE COSMONAUTS – 17

By Cordon R. Hooper
(Continued from October 1979 issue.)

Lt-Col. Georgi Ivanov Ivanov
Georgi Ivanov was born on 2 July 1940, in the town of Lovech, in Bulgaria. His father Ivan Ivanov is a retired electrical technician with the Power Supply Administration of Bulgaria, while his mother Anastasia Georgieva is a housewife. In 1955, Ivanov became interested in flying, and within a year he was among the most active members of the local model flying club, and had begun making parachute jumps. In 1957, he completed the initial course in gliding at the airclub in Preven, and in less than a year he was piloting a plane.

He finished school in 1958 and enrolled in the Georgi Benkovski Higher Air Force School near Dolna Mitropoliya, not far from Preven. He graduated in 1964 as a Lieutenant, with the diploma of engineer-pilot, and became an instructor at the School. In 1967, he was promoted to Coach-pilot 2nd class, and in 1968, he became a Coach-pilot 1st class. He also joined the Bulgarian Communist Party in 1968. Ivanov later served in the anti-aircraft units of the Bulgarian Air Force as a flight commander and squadron leader, and was awarded the title of Military pilot 1st class, together with medals for exemplary service. He has logged more than 1900 hr. flying time.

Following the agreement to fly non-Soviet cosmonauts from member countries of the Intercosmos programme onboard Soyuz and Salyut spacecraft, Bulgaria began a cosmonaut selection programme. The two finalists were Ivanov and Alexander Alexandrov, and they began their training at Star Town in March 1978. Ivanov was eventually chosen for the mission, and he therefore flew as cosmonaut-researcher onboard Soyuz 33, launched on 10 April 1979. The aim of the mission was to dock with the already-manned Salyut 6 space-station and spend a week onboard carrying out a series of joint Soviet Bulgarian experiments. Unfortunately, during the final stages of the rendezvous manoeuvres, the approach engine malfunctioned, and the mission was immediately aborted. Ivanov and Nikolai Rukavishnikov made an emergency return to Earth, involving a ballistic re-entry. The descent module touched down after a flight lasting just 1 day 23 hr. and 01 min.

Although the mission was a failure, Ivanov returned to a Hero's welcome, and received many awards and honours, including:- the title of Hero of the Soviet Union, with Gold Star Medal and Order of Lenin; the title of Hero of the People's Republic of Bulgaria, with Gold Star Medal and Order of Georgi Dimitrov; the title of pilot-cosmonaut of the People's Republic of Bulgaria; the title of Merited-pilot of the PRB; the honorary badge of Sofia, 1st class; honorary citizenship of Omourtag and Lovech; and the honorary badge of Botevgrad, Bulgaria. He was also promoted from Major to Lt. Colonel.

7. Lt-Col Georgi Ivanov.

Ivanov – known to his friends as Gosho (an abbreviation of Georgi) – is married. His wife Natalia Rousanova works in the public service sector, and they have a 12 year old daughter, named Annie (or Ani.) Rukavishnikov once described Ivanov as "cordial and friendly, with a good sense of humour. A tireless worker. Strong-willed and determined." The psychiatric reports carried out by Bulgarian specialists during preparations for the mission said of Ivanov: "Definitely positive traits, stable and mature character. Strong, mobile, even-tempered type of nervous system. High emotional, moral and psychological stability, excellent flying qualities, rich flying experience. Perfect health and fitness, high physical endurance."

Georgi Ivanov's hobbies include reading and underwater fishing, and he is also a good skier.

Captain-Engineer Alexander Alexandrov
Alexander Alexandrov was born on 1 December 1951, in the town of Omourtag, in Northern Bulgaria. His father Panayot Alexandrov is a forester.

The Cosmonauts – 17/contd.

Alexandrov studied at the Georgi Benkovski Higher Air Force School near Dolna Mitropoliya, not far from Preven. During his first or second year at the school, he crashed into a tree during a parachute jump and was badly injured. He was absent from studies for two to three months, but upon his return, he quickly caught up with his colleagues, and even managed to overtake many of them. He joined the Communist Party of Bulgaria in 1972, and graduated from the Higher Air Force School as a pilot-engineer in 1974. Upon graduation, he served in the anti-aircraft units of the Bulgarian Air Force.

Following the agreement to fly non-Soviet cosmonauts from member-countries of the Intercosmos programme onboard Soyuz and Salyut spacecraft, Bulgaria began a cosmonaut selection programme. The two finalists were Alexandrov and Georgi Ivanov, and they were sent to begin their training at the Yuri Gagarin Cosmonauts Training Centre in March 1978. Ivanov eventually flew the mission as cosmonaut-researcher onboard Soyuz 33 launched on 10 April 1979, while Alexandrov served as back-up, and possibly as CapCom in MCC.

Following the completion of the mission, Alexandrov was awarded the Order of the People's Republic of Bulgaria, 1st Class, for his persistence, conscientiousness and dedication during preparation and training for the flight. He was also promoted from Lt. Engineer to Captain-Engineer, awarded the title of Merited Pilot of the People's Republic of Bulgaria, and made an honorary citizen of Omourtag.

Alexandrov – known to his friends as Sasho (an abbreviation of Alexander) – is unmarried. He has a keen sense of humour, and it is said that he could have been an actor but for his ambition to become a pilot. He is an excellent trumpet player.

THE ARIES SOUNDING ROCKET

By Dave Dooling

Introduction

Obsolete ballistic missiles once headed for demolition are being used as cheap, versatile sounding rockets by U.S. military and civilian agencies.

Space Vector Corp. of Northridge, Calif., is using the motors from the Minuteman ICBM for a family of sounding rockets called Aries, and for Army and Air Force tests.

"Fat Albert"

Aries began in 1974 following discussions by the Naval Research Laboratory, Sandia Laboratories (a major energy and nuclear weapons firm), and others who felt they might benefit from a larger class of sounding rockets briefly nick-named "Fat Albert". The idea was to use stages from Minuteman I ICBMs that were being phased out by the Minuteman II and III models. At the time, the stages were being destroyed. Arms limitation treaties made it unlikely they would be redeployed, and future replacements were likely to be a new family of ICBM. (The arms treaties did not require destruction, but only limited the number of missiles that could be ready to launch).

So, the Air Force was persuaded to salvage 60 first-stage and 130 second-stage motors. Currently only the second stage is being used in sounding rockets, but a two-stage Aries and two Aries satellite launchers have been studied. In addition, modified Minuteman missiles – using first and second stages – will be used in military test programmes.

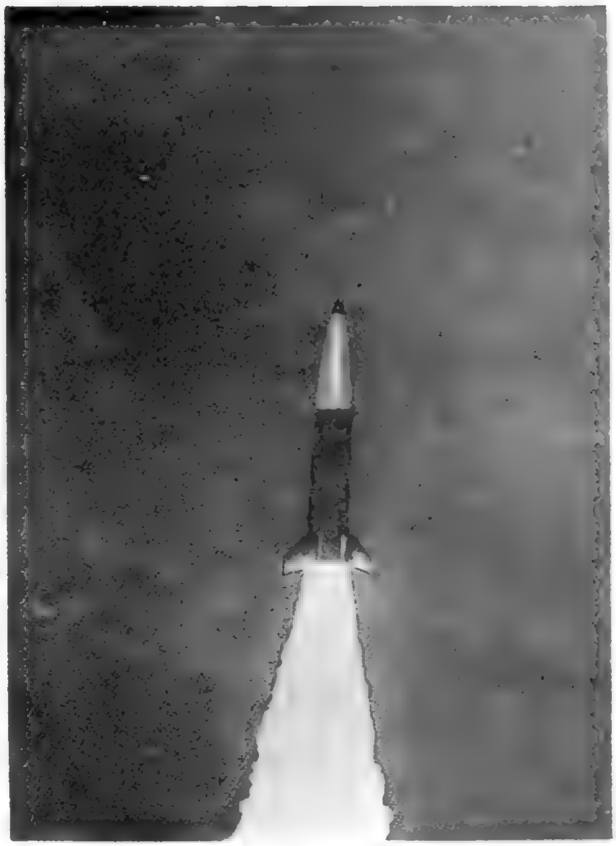
The second stage of the Minuteman is designated M56A-1. At lift-off it generates 46,000 lb of thrust. Burn duration is 60.13 seconds with a total impulse of 2.82 million lbf-sec. Stage weight is 12,015 lb.

Several modifications to the M56A-1 were necessary to adapt it to sounding rocket use. The first and most touchy was the four exhaust nozzles. Because they were designed for high-altitude, they have an expansion ratio appropriate to a vacuum. They had to be cut short to provide stable exhaust at sea level.

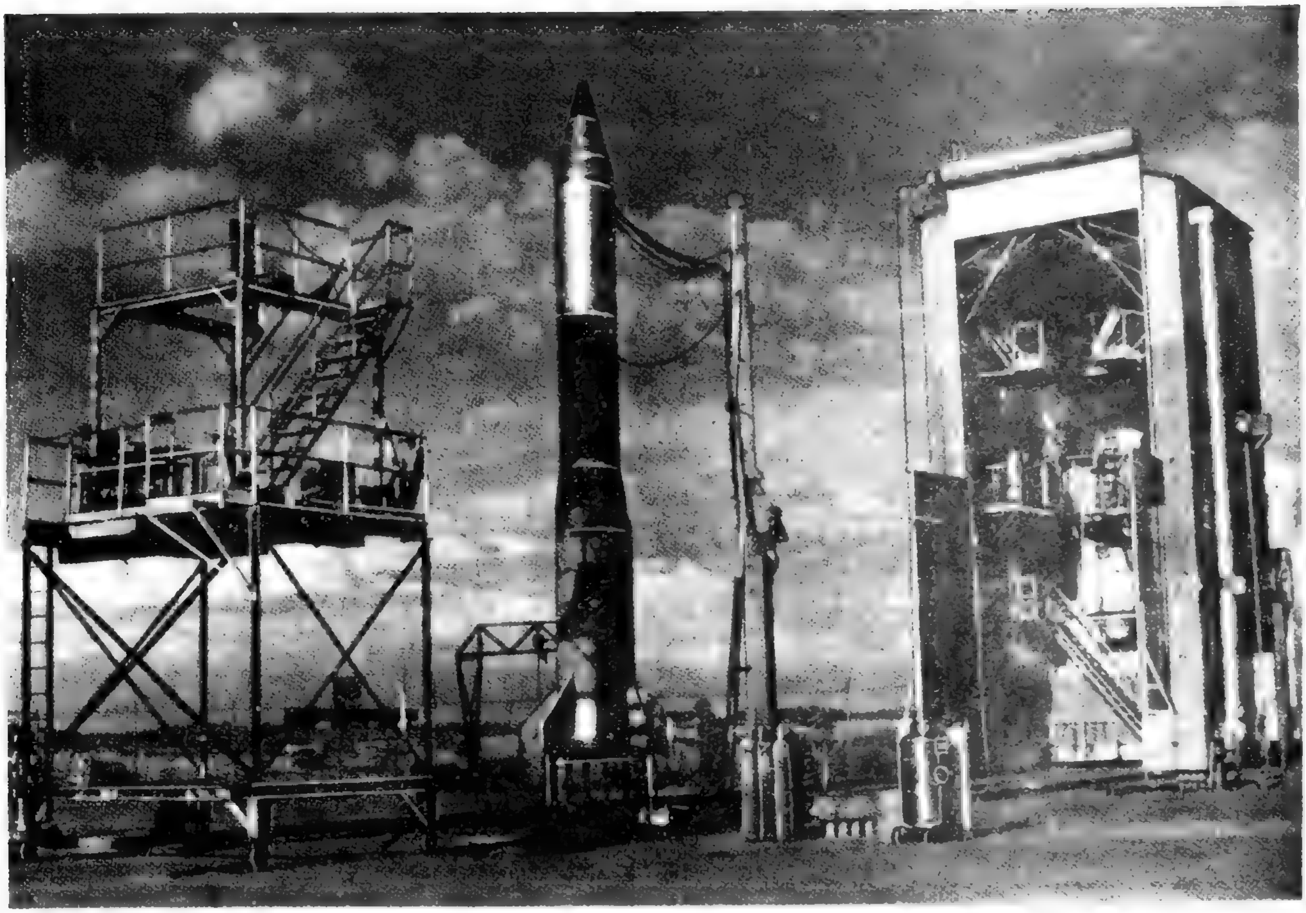
Other modifications include new nozzle control units, an aft skirt with fins, and a guidance control unit. Following the later failure of two Aries rockets, a heat sink was added to the forward dome to prevent burn-through. Space Vector does not own the stages, but serves as integration and operations contractor.

Payloads

Payload for the Aries ranges from 1,500 to 3,500 lb boosted to altitudes of 650 to 370 miles (with greater weight, lesser altitude is achieved). Payload diameter is 44 in, more than double the 17 in. standard with many sounding-rockets. Cost per flight is about $300,000, a figure that reflects the cost of modifying and launching as the stage was paid off several years ago. This is still quite cheap compared to many sounding rockets.



8. NASA-IMS Aries rocket with Max Planck payload ascends from White Sands Missile Range, New Mexico, 18 August 1975.
Space Vector Corporation



9. Aries rocket on launch pad at White Sands Missile Range.

Payloads for Aries have included magnetospheric tracers, X-ray and extreme ultraviolet astronomy, and military infrared experiments. A major instrument already flown aboard Aries is a large X-ray telescope co-sponsored by NASA and the Mullard Space Science Laboratory and National Physical Laboratory in Great Britain. With guidance systems developed by Space Vector, pointing accuracies down to 1° are possible (as the company's name implies, guidance systems were their original business).

An Aries II sounding rocket has been studied but has yet not flown. This would use the Minuteman second and third stages (M56A-1 and M57A-1). Such a vehicle would carry 38 in.-diameter payloads weighing from 1,000 to 2,000 lb up to 650 to 370 miles. Aries II is being considered for IRBM experiments, but might also be of use to launch materials processing experiments requiring long periods of low gravity.

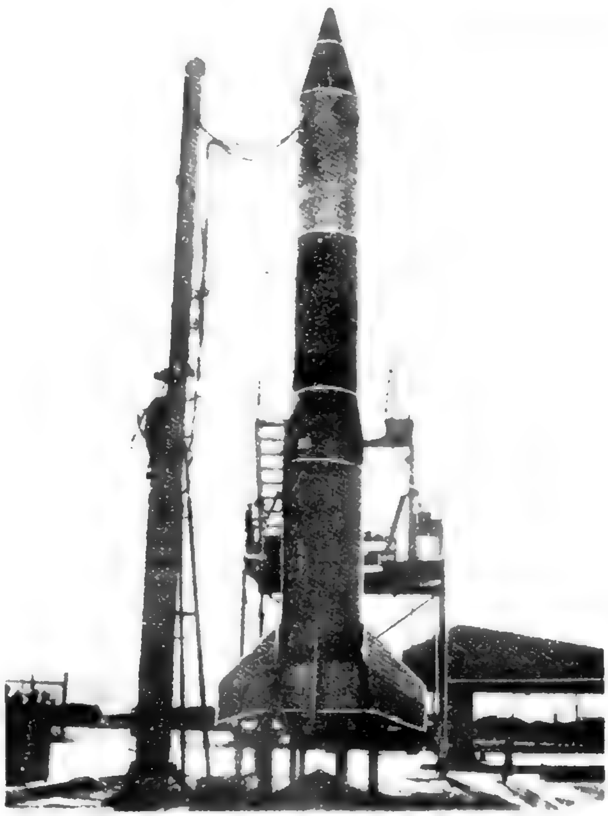
The M57A-1 motor weighs 4,309 lb, burns for 59 seconds at 17,085 lb of thrust for a total impulse of 1 million lbf-sec.

Defence projects

Space Vector will provide similar integration and launch services to the Air Force and Army for defence projects. Both will use the first and second stages of the Minuteman. The Air Force effort is the multi-spectral measurements programme for recording the optical signatures of reentry vehicles. The Army's homing overlay experiment will demonstrate a non-nuclear-kill anti-missile warhead.

The most advanced Aries uses studied are two satellite launchers which appear promising but are unlikely in the Space Shuttle era.

The Aries Orbiter would use the Minuteman first and second stages, plus a standard third stage injection motor, for



The Aries Sounding Rocket/contd.

satellites weighing up to 200 lb going into 200 to 800 mile high orbits. Controls would be the same as those being developed for the Air Force programme.

All three Minuteman stages and a spin table/motor would make up the Aries IV, a vehicle with geosynchronous capability. From a launch site at the equator, a 150 lb communications satellite could be placed on station.

Although NASA pressure is likely to keep such vehicles on paper, Space Vector's president, Richard Rasmussen, said, "You could run any other dedicated vehicle up an alley, cost-wise."

Aries may be felt in the Shuttle programme, nevertheless. NASA and other payload planners are considering designing 44 in.-diameter payloads that can fly both the Aries, for initial checks and quick quick-reaction flights, and the Shuttle, for long duration at low cost. For further information, contact: Space Vector Corp., 19631 Prairie St., Northridge, CA 91324.

The author is indebted to Richard Rasmussen of Space Vector for supplying material used in this article.

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"ODIN" – THE TENTH PLANET – A NEAR DISCOVERY IN 1795?

By A. T. Lawton

Introduction

The name used in the title of this note is not official, but was selected by M. Hammerton for his and Dr. Rawlin's private use when they were studying possible parameters for a tenth planet [1, 2]. I fully agree with Dr. Hammerton's comments, i.e., there is no "monopoly on the use of Latin or Greek" in the naming of Solar System objects, and I have therefore adopted this unofficial name for convenience in writing this paper.

An "historic" discovery?

Since writing the article dealing with the tenth planet, I have been further considering the inexplicable action of Joseph Jerome Lefrancais de Lalande who was compiling a star catalogue (*The Histoire Celeste*) in the latter part of the 18th and early part of the 19th century. When finally published, the catalogue listed the accurate positions (for the time) of nearly 47,400 stars and was a monumental piece of dedicated effort.

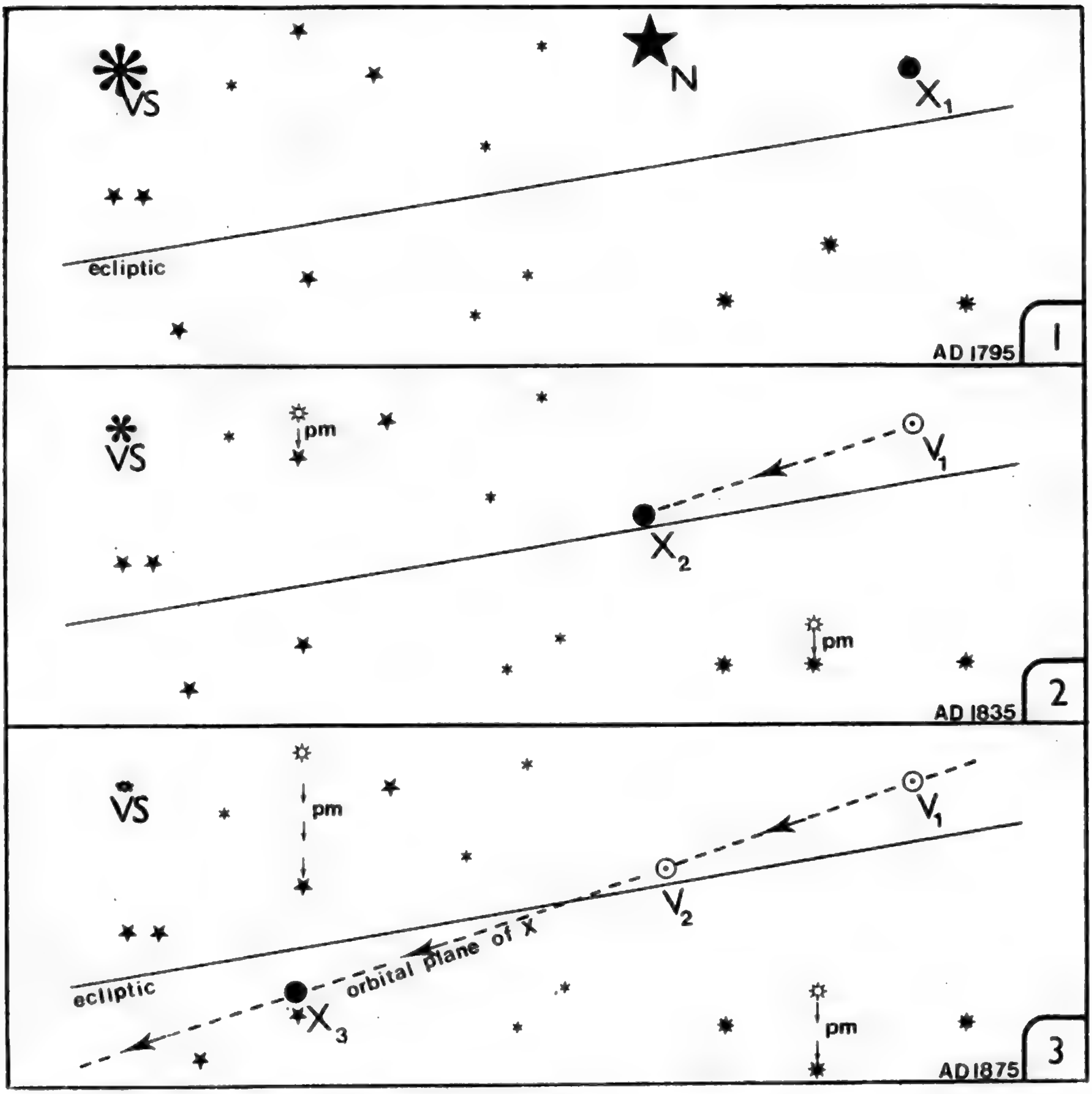
But there is at least one entry in the Histoire which is *not* a star but a *planet* – and that planet is Neptune! This was proved after 1846 by "back tracking" the computed orbit to look for such sightings, and a remarkable incident was uncovered when Lalande's detailed notes were examined. He had noted and plotted the position of a "star" on 8 May 1795, and during the course of re-checking on 10 May, he found that the same object occupied a different position. For some reason or another we will never know, Lalande decided that the 8 May record was wrong but the one for the 10 May was right. Consequently he missed discovering another major planet in the Solar System, and as I will point out later, he may have missed much more.

Writing almost a century later in 1886, [3] Sir Robert Ball neatly summarizes the position, "Had Lalande possessed a proper confidence in his own observations an immortal discovery lay in his grasp; had he manfully said, 'I was right on the 10 May and I was right on the 8 May; I made no mistake on either occasion and the object I saw on the 8th *must* have moved between that and the 10th', then he must without fail have found Neptune. But had he done so how lamentable would have been the loss to science!"

Sir Robert is of course referring to the discovery of Neptune by mathematical prediction (Adams and Leverrier) rather than by direct methodical observation. With hindsight and due respect, I beg to differ from Sir Robert's opinion, for *if* Lalande *had* discovered Neptune, then admittedly the honour would have gone to a Frenchman. But this is more than counterbalanced by the fact that we would have had over *50 years added* positional data for Neptune – and this at a possibly most critical time. If we refer to the tables of Rawlins' and Hammerton's paper [4] then we see that Lalande's data (for both 8 and 10 May) indicate that Neptune was perturbed a full 7.2 arc seconds from its predicted orbit – a perturbation that was *not* repeated when Neptune passed through the same area of sky in 1961. If this perturbation *was* due to another body, then had Neptune's real identity been uncovered in 1795, many well known observers would have noted the diminution of the perturbation – and been very suspicious. 7.2 seconds of arc may not seem much but it would be outside the known telescopic errors of Bouvard, the Herschels, Galle, and other contemporary observers. The errors observed for Uranus were 20 arc seconds – about three times the possible observed perturbation of Neptune.

The interesting hypothetical scenario then arises whereby Adams and Leverrier would have become interested in the residuals of *Neptune* and started calculations for the perturbing body – "Odin"! If the latter has the highly elliptical orbit that I suggested in Ref. 1. then they would have been wrong to assume a near circular orbit in accordance with Bode's Law, which would place it at a mean distance of 77AU. However the 50 years of accumulated observations of Neptune would have given *some* indication of where to look, and since "Odin" would still be fairly close to perihelion and moving at a leisurely pace compared to Neptune, it is possible that either Adams or Leverrier would eventually have produced a viable solution, i.e., one which placed the errors within a reasonable area of sky and did not require the observation of too many stars. In 1846 "Odin" would have been about 40AU from Earth and therefore comparatively close, and consequently astronomers could have been forgiven if they thought they had found another massive planet. Successive observations would have established the elliptical nature of the orbit hypothesised in Ref. 1. and subsequently revised the diameter and mass of "Odin".

Ironically enough, *if* Lalande *had* discovered Neptune and "Odin" was also found, it is now likely that we would firmly talk of a 9 *planet* Solar System – *albeit*, nearly twice its present



11.'LIGHTWEIGHT' PLUTO NO LONGER ACCOUNTS FOR THE PERTURBATION OF NEPTUNE AND A MORE MASSIVE 'TENTH PLANET' IS ONCE AGAIN OPEN TO CONJECTURE.

Fig 1. Stages in the plotting of a possible planetary orbit by reference to catalogues with separation intervals of (say) 40 years, together with some of the confusing hazards confronting a would-be searcher. VS is a variable star brilliant in 1795, hardly visible in 1875. N is a nova whilst pm is the proper motion of stars that have noticeably moved. X is an object that has originally been plotted as a star but has moved in a definite and fast manner against the background stars. It leaves 'vacancies' (V_1, V_2) and from these the orbital path can be determined. Since the orbit seems to be close to the ecliptic, a possible planetary body could be suspected. Future positions of X can therefore be predicted and the search continued. Although this is a purely hypothetical chart it may just be possible to detect a hitherto unknown planet if the areas adjacent to Neptune (plotted as a star in old catalogues) are thus thoroughly checked over the period 1700 – 1900. It is possible that such an object was angularly close to Neptune in 1795.

Odin – The 10th Planet – A Near Discovery in 1795/contd.

known size. The Neptunian perturbations would be so accurately accounted for, that Pluto would not have been actively sought, and it therefore would have been found by accident much as Kowal found Chiron [5]. Thus the discovery of Pluto could have been delayed by about 50 years and we possibly may not yet have found Charon – Pluto's relatively large satellite! The Solar System would be "different".

Was "Odin" seen by Past Observers?

We may ask this question if Lalande's observations are believed to be accurate, for if such is the case then "Odin" was both physically *and* angularly close to Neptune and as such may possibly have been recorded by Lalande as yet another "star". Theoretically then we should examine and note all the stars recorded in the *Histoire Celeste* whose positions were (say) 10 degrees away from that recorded for Neptune on 8 and 10 May 1795. Then the same stars could be checked on a later catalogue – say the *Bonner Durchmüsterung* (prepared during the 1840's – 1850's by Galle and Argelander, the actual finders of Neptune). Further comparisons might be done with even later catalogues. In this hypothetical experiment particular attention would be paid to the plane of the ecliptic, the region where planets are most likely to be found. The would be searcher checks the catalogues for "missing stars", i.e., places where stars are reported in one position in one catalogue and in another position in a different index. The principle is illustrated in Fig. 1 which shows the planet's track in terms of "missing stars".

Although this may look simple on paper it would be laborious and very liable to error and mis-interpretation. The examination and checking could be upset by any of the following:–

(a) Several true stars will have shifted position due to their normal proper motion in the interval between compilation of the catalogues.

(b) Some variable stars will have changed in brightness in the compilation interval. This will cause problems if the variable reaches a minimum which is below the capability of the observer's telescope, a good example of this happening being the discovery of Mira (*Omicron Ceti*) in 1596 by David Fabricius. (Other astronomers did not believe him).

(c) The brilliance of the *sought-for planet* is below the capability of the telescopes of one or the other of the catalogue's researchers.

(d) An object catalogued as a "star" may be a comet at or near aphelion, or even worse, an asteroid or planetoid but NOT the one being sought.

Astronomy has had a long history of overlooked planets and asteroids. Uranus was sighted some 19 times and repeatedly logged as a "star"! Pluto had been photographed several times before discovery and Chiron (the latest asteroid) was pre discovery photographed 30 times, the earliest being 1895! If, after making due allowance for the above items, it is found that a series of presently non-existent "star positions" lie close to the ecliptic and plot out a possible planet path, then the case for there being an unknown planet following the orbit outlined in Ref. 1., would be strengthened.

The chances of finding "Odin" by such research is admittedly slim, and in the paper of Ref. 1, I mentioned that the maximum brightness of such a planet would be about magnitude 11. This is one magnitude down on Lalande's *The Histoire Celeste* – but there is always the hope he recorded it – as he recorded every starlike object he could see. In the same vein I would like to consider that the Neptune sightings by Lalande were accurate. The only reason for *not* being able to attach *real* statistical weight to his observations is that there were only two, and Lalande himself was only confident of one!

Conclusion

If Joseph Jerome Lefrancais de Lalande had discovered Neptune by (say) 1796 then by the 1850's I feel that we would have proved the presence (or absence) of "Odin". We might also know by observation of the latter, if there were any further planets, or if "Odin" did indeed mark the outer boundaries.

If such a planet is following the path described in Ref. 1. then we will not see it in the 1795 position until AD 2290 by which time we may have developed more sophisticated ways of detecting planets and of dispatching space probes to uncover their secrets. This applies equally to the planets of other Solar Systems – the BIS Project Daedalus study is merely the beginning! By 2290 a manned expedition could well have visited "Odin" (presuming it exists) to monitor the subtle changes of atmosphere and surface as the planet moves from aphelion to perihelion, as described in Ref. 1.

As St. Paul succinctly wrote nearly 2000 years ago "Faith is the substance of things hoped for, the evidence of things not seen".[6]

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11A. VOLCANIC MOON. This dramatic view of Jupiter's satellite Io shows two simultaneously occurring volcanic eruptions. One can be seen on the limb (at lower right) in which ash clouds are rising more than 150 miles (260 km) above the satellite's surface. The second can be seen on the terminator (shadow between day and night) where the volcanic cloud is catching the rays of the rising Sun. Voyager 1 photo from 2.6 million miles (4.5 million km).

National Aeronautics and Space Administration

JUPITER'S BIGGEST MOON

Following publication in this journal of the first pictures of the moons of Jupiter obtained by the Voyager spacecraft, we have received many requests from readers to show the topography of these remarkable bodies in greater detail. In this issue we focus upon Ganymede, Jupiter's largest satellite.

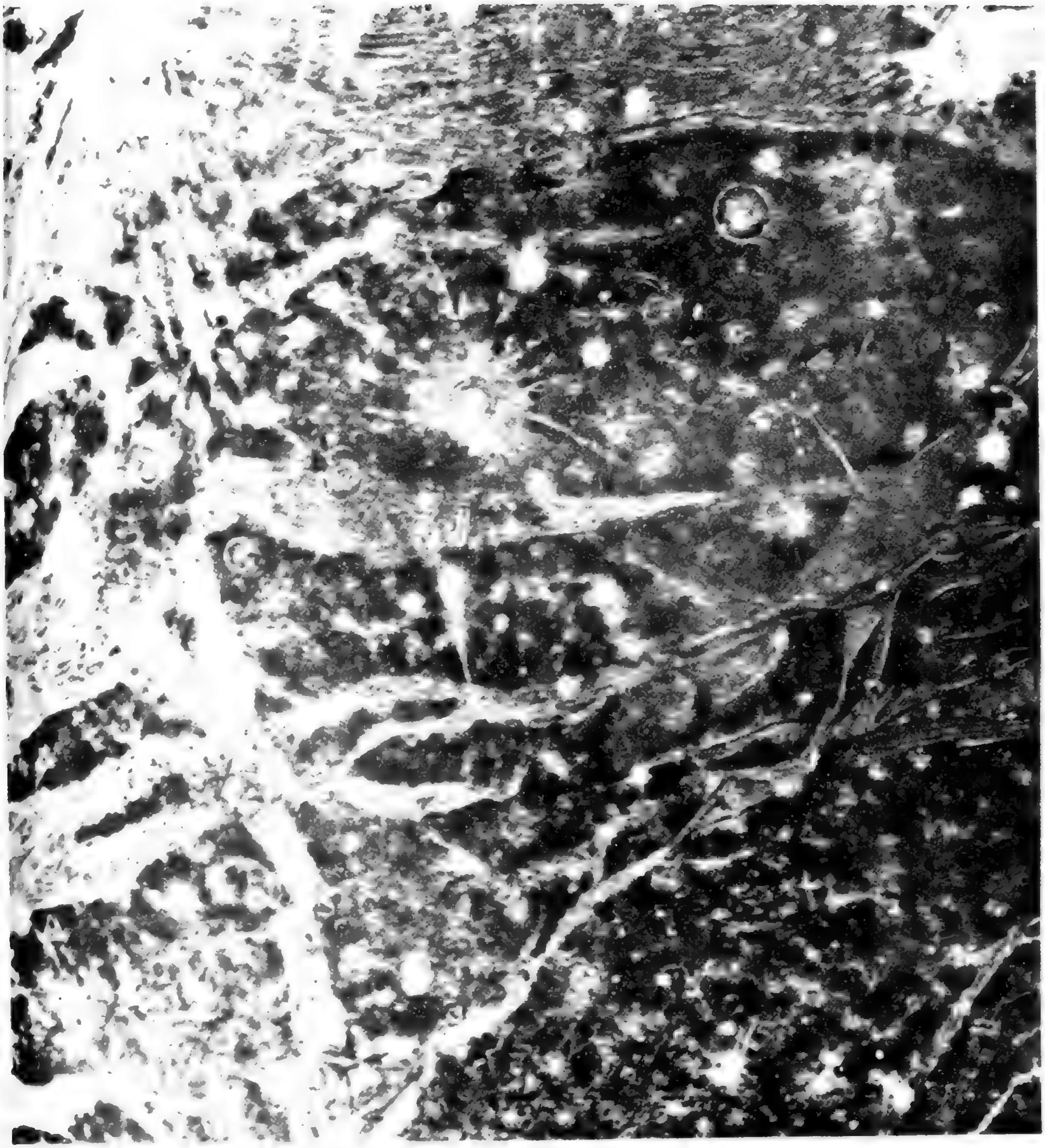
13. CONTINENTS OF ROCK AND ICE. This picture of Ganymede was taken on 5 March 1979 from a distance of 272,000 km; the centre lies at 13 deg latitude, 359 deg longitude. Many bright impact craters are seen that have radial ejecta patterns. These rays lie across and therefore are younger than the bright and dark background material. Many older impact craters are shown that have lost their rays probably by impact erosion. The bright background areas contain grooves and ridges that may be caused by faulting of the surface materials.

This special feature has been prepared in collaboration with the Jet Propulsion Laboratory, Pasadena, California

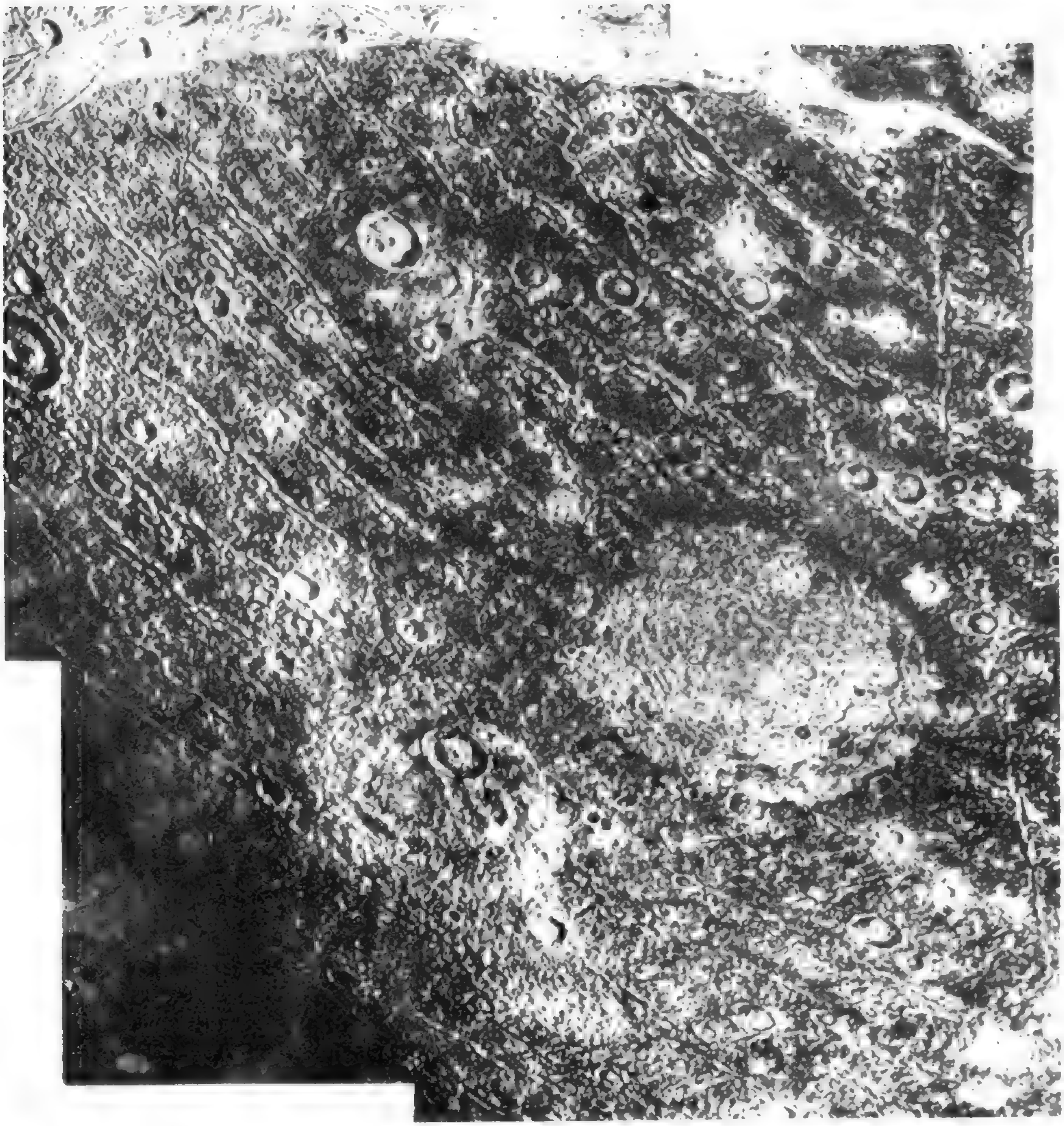
14. GANYMEDE has a diameter of about 5200 km - about 1.5 times that of the Moon. However, it has a bulk density of only about 2.0 g/cc (almost half that of the Moon) and is probably composed of a mixture of rock and ice. This sector was photographed by Voyager on 5 March 1979 from a distance of 253,000 km (151,800 miles). The picture is centred at 66 deg south latitude and 3 deg longitude and shows the south western limb region. The smallest features visible are about 2.5 km (1.5 miles) across. The surface shows numerous impact craters, many of which have extensive bright ray systems. Light bands traversing the surface contain alternating bright and dark lines which probably represent deformation of the icy central material.

Jupiter's Biggest Moon/contd.

15. This picture of the surface of Ganymede was taken on 5 March 1979 as the spacecraft closed to a distance of only 145,000 km (87,000 miles). The width of the picture represents about 580 km on the surface, and the smallest visible features are about 3 km (1.7 miles) across. The picture shows complex patterns of ridges and grooves which are probably the results of deformations of Ganymede's thick icy crust. Some systems of grooves and ridges are superimposed on the ridge and groove systems indicating that they are younger. A more degraded crater near the left centre of the picture is crossed by ridges indicating that it predates the period of crystal deformation.



16. Another shot of the surface on 5 March shows Ganymede from a distance of 246,000 km (158,400 miles). The centre of the picture is at 19 deg south latitude and 356 deg longitude, and the height of the frame represents a distance of about 1000 km (600 miles) on the surface. The smallest features seen on this photo are about 2.5 km (1.5 miles) across. The craters lacking ray systems are probably older than those showing rays. Bright bands traverse the surface in various directions; they contain an intricate system of alternating linear bright and dark lines which may represent deformation of the crusted ice layer. A bright band trending in a north-south direction in the lower left-hand portion of the picture is offset along a bright line. This offset is probably due to faulting. Two light circular areas in the right upper centre of the picture may be scars of ancient impact craters which have had their topographic expansion erased by flowage of the crystal icy material.



17. This picture of Ganymede was taken from a distance of 85,000 km (53,000 miles) by Voyager 2 as it approached Jupiter. A large variety of impact craters of different ages are shown. The brightest craters are the youngest. The ejecta blankets fade with age. Shown in the centre is a bright patch that represents the rebounding of the floor of the crater. The dirty ice has lost all topography except for faint circular patterns. Also shown are the 'Callisto type' curved troughs and ridges that mark an enormous impact basin. The basin itself has been destroyed by later geologic processes. Only the ring features are preserved on the ancient surface.

All photos: Jet Propulsion Laboratory, NASA.

RADIO TELESCOPES IN SPACE

By Yuri Kolesov

Introduction

A group of leading Soviet astrophysicists and designers of space technology has put forward a design for a large orbital radiotelescope (*Spaceflight* October 1979 p. 423). The idea is not altogether new but this is the first time it has got so far; practical engineering calculations have been carried out and the technical problems connected with the operation of the telescope have been discussed.

Radio astronomers have always tried to increase the sensitivity of their instruments and nowadays there are radiotelescopes capable not only of locating very distant sources of radio emission, but of resolving their structure as well. And in comparison with the very first telescopes, which were inferior even to the human eye, modern equipment has a very high resolving power.

Radiointerferometry

Initially, only single radio antenna were employed. These were fixed to point in one direction only, so due to the Earth's rotation, the radio sources observed continuously shifted across the sky. By rotating the antenna on its base radio astronomers were able to track the sources all the time. The largest rotating antennae today may reach the proportions of a soccer pitch and weigh up to several hundred tonnes. At present the manufacture of radio antennae is limited by modern engineering techniques.

In the early 1950s astrophysicists stepped into a new age when researchers in different countries began using two dish antennae to receive radio signals. The resolving power of such an installation, known as a radiointerferometer, is much greater than that of a single antenna and is determined not only by the size of each antennae dish, but also by the distance between them.

A global network of radiointerferometers is at present operational. This includes the largest telescopes in Australia, Britain, Canada, Holland, the USA, the USSR and West Germany. Their combined resolving power is phenomenal – the position of an object on the Moon can be determined within a distance of 20 cm.

This may seem very satisfactory, yet such resolution is already inadequate. The recently discovered quasars, pulsars and active galactic nuclei have extremely small angular dimensions. Even the global interferometer is incapable of resolving them. The system as it stands cannot be extended any further since radio antennae on opposite sides of the world are already in use.

Radiotelescopes in Space

The latest idea is to place radiotelescopes into space, the antennae dishes being constructed from separate 200 metre units. To begin with they would be put into a low Earth orbit where the radiotelescope would be assembled either by robots or by the crew of an orbital station (10-15 men would be required for manual assembly). After assembly, the telescope would be accelerated to a high speed with the use of special rocket engines and transferred into a heliocentric orbit.

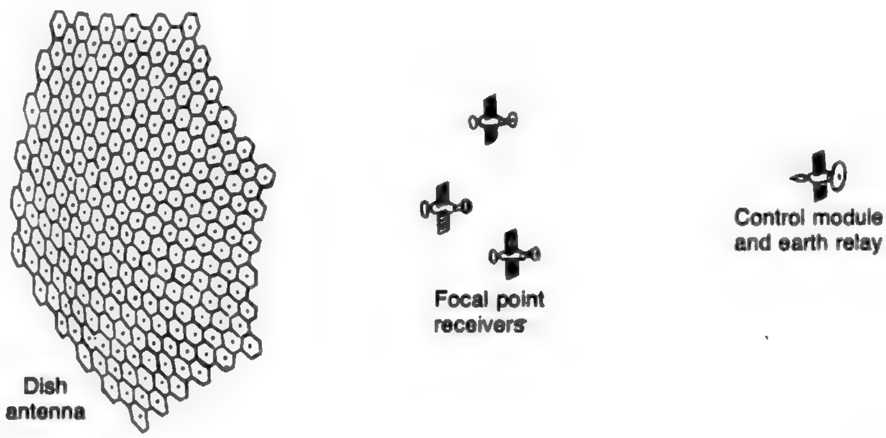
The dimensions of the completed assembly would be between 1 and 10 kilometres across and the radiotelescope would be able to operate on its own or coupled with another similar telescope, the two together forming an interferometer.

With modern space communications it would be possible to place one of the antenna in near-Earth orbit while sending the other into an orbit of Saturn. The distance between them would be approximately 1,500 million kilometres, which together with the enormous dimensions of each aerial dish, would give such a system a sensitivity and power of resolution many hundreds of thousand times greater than that of the best interferometer on Earth today. This would open the door to studies of far distant objects, including planets revolving around other stars – these are the planets considered the most likely to be inhabited, if any other civilisations exist at all.

Telescopes orbiting other planets will have another immense advantage. It will be possible not only to vary the distance between the antennae but to also change their direction of orientation. Up to now, observers on Earth have only had a flat two-dimensional representation of the Universe. Cosmic telescopes will enable us to view everything from a new angle. With their aid, radio astronomers will for the first time have the opportunity to view distant objects from their previously "blind side" and thus obtain a three-dimensional picture of the Universe.

"The detection of planets, planet-like bodies and cooled stars" is listed as one of the main lines of investigation in the official USSR Academy of Science programme of studies on problems of contact with extraterrestrial civilisations.

The search for artificial radio signals has been going on for a long time, but so far without any success. Are we simply incapable of picking up any artificial messages? With the introduction of orbital telescopes our chances of finding any messages of this kind will greatly increase.



18. Soviet design for the large orbiting radio-telescope described in this article.
Novosti Press Agency

ASTRONOMICAL NOTE BOOK

By J. S. Griffith*

SOLAR SYSTEM
Occultations of Stars by Solar System objects

Following a summary of the successes of observations of stellar occultations by objects in the Solar System, predictions of eleven occultations of stars by Ceres are made.

Occultations of stars by the Moon have often been used to give more accurate positions both of the star and of the moon. Recently high speed photoelectric photometry has been used to give accurate stellar diameters and evidence of steller multiplicity.

In ref. [1] the application of occultation techniques to other objects in the Solar System is summarized. Here the principal interest is in the properties of the occulting bodies, and results on the atmospheres of Venus, Mars, Jupiter, Uranus and Neptune are cited. The ring-system of Uranus was discovered by analysis of occultation results, and the diameters of Io and several asteroids determined. Even the body shape of an asteroid has been found. Evidence has also been discovered that some asteroids are multiple and have their own satellites (ref. [2], [3]).

The International Astronomical Union's Commission 20 set up a working group in 1976 to predict occultations by satellites and asteroids. Occultations by Neptune (and any ring system it may have), Pluto, Saturn and some satellites of Saturn have been predicted.

For the asteroid Ceres, with twice the diameter of the next largest asteroid (Pallas) predictions are made in ref. [1] of occultations in 1979/80 and it is pointed out that more precise measurements of its diameter and hence density will also improve our knowledge of the density of Vesta.

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STARS
Sound Waves in early-type Stars

The existence of rapidly growing sound waves in the expanding atmospheres of hot stars is demonstrated. Strong sound waves with periods from 15 minutes to several hours are expected, with possibly sufficient energy to heat a corona.

Following a theoretical analysis of the problem, the author of ref. [1] points out that it has been found that many O- and B-stars have photospheric macro-turbulent velocities of the order of the local sound speed (ref. [2]) and that there is a strong correlation between large macroturbulent velocities and large outflow velocities in the outer layers, correlated with large mass losses.

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Supernovae as Extragalactic Distance Indicators

Type II supernova observations are used in conjunction with numerical light curve models to derive distances. It is proposed to use the method to estimate Hubble's constant, and with the space telescope to help decide whether the Universe is open or closed.

Determining distances in astronomy has always been a difficult task. The methods used (in order of increasing distance from the Earth) include radar, trigonometrical parallex, main sequence fitting (apparent absolute magnitudes), cepheid variables, brightest blue stars and variable stars, supernovae, luminosity function of clusters of galaxies, and the Hubble redshift law. In ref. [1] a refinement of the supernovae method is presented, where theoretical light curves are fitted to individual observations of Type II supernovae to infer distances. Reasonable agreement with other methods is found, and the advantages cited include the absence of the requirement that the supernova be discovered at maximum; only traditional colour photometry is required; no measurements of effective temperature or photospheric velocity are required; use of a self-consistent model allows identification of a set of more nearly homogeneous events and eliminations of abnormal ones. The method is currently being applied to all available data on Type II supernovae.

With the advent of the space telescope, photometry down to 27th magnitude or fainter will be possible. The technique could be used to place limits on the deceleration parameter q and help us decide whether the Universe is open or closed.

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A bizarre object

Stephenson-Sanduleak 433 is a peculiar 14th magnitude emission-line object associated with a variable nonthermal radio source and probably also with the X-ray source A1909+04. Its broad intense Balmer, He I and He II emission lines vary dramatically in profile and intensity on a time scale of one day (ref. [1]).

The most bizarre spectral features are three very strong broad emission features in the green, red and near-infrared which change in intensity, profile and wavelength daily, but with no apparent connection. The wavelength shifts are up to 600 Angstroms in 30 days. These features appear to be Doppler shifted Balmer lines at displacements corresponding to velocities of from 20,000 to 50,000 km/s^{-1}.

Further discussion and possible explanation is promised in a subsequent paper.

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GALAXIES
Dynamics of compact groups of galaxies

In compact groups of galaxies, one would expect to find a diffuse background of tidally stripped material if numerous strong gravitational encounter had occurred. It is found that little or no such evolution has occurred, showing that compact groups are transient configurations, occasionally forming within surrounding looser groups. N-body simulations confirm the observations.

The search for diffuse light in two southern compact groups was undertaken using the 4 m telescope of the Cerro Tololo Inter-American Observatory (ref. [1]). An upper limit of the order of 6% of the total light in galaxies was found for the amount of diffuse light, indicating very little dynamical evolution.

Estimates of the expected amount of tidal stripping in compact groups, if they are permanent structures, yield a

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figure of 75%. Even though this estimate is subject to various uncertainties, it seems certain that more than 5% of the luminous material will be tidally stripped.

It appears that compact groups are transient compact configurations forming occasionally within loose groups.

Simulations of a number of loose groups using an N-body computer code were carried out. The compact groups were found to be transient subsystems temporarily forming within looser groups. The groups are unbound (positive energy) and eventually disperse into the larger entire group in a time of the order of the group crossing time.

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A Massive Galaxy

A rotation curve derived from radio observations of the spiral galaxy NGC 1961 indicates that its mass exceeds 10^{12} solar masses, making it the most massive spiral known. Further optical observations give evidence for peculiar and unexplained motions within the system.

Using the National Radio Astronomy Observatory's 300 ft (92 m) transit telescope, the authors of ref. [1] obtained neutral hydrogen measurements of NGC 1961. The neutral hydrogen mass alone is similar to the *stellar* mass of a typical galaxy while the total mass of NGC 1961 exceeds 10^{12} solar mass, over three times the known mass of any other galaxy. It is possible that 2×10^{8} years ago a burst of star formation took place, perhaps triggered by a violent dynamical event such as interaction between a massive spiral galaxy and a companion.

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QUASARS

21 centimetre absorption lines in a quasar spectrum

Detection of redshifted neutral atomic hydrogen in absorption toward the quasar 1229-021 implies either a velocity of ejection from the quasar of about one-third the velocity of light or, if the absorption is due to an unrelated cloud along the line of sight, then the presence of previously detected optical absorption lines of magnesium at the same redshift as the hydrogen gives a magnesium to hydrogen abundance in the cloud close to the solar ratio.

We do not expect neutral hydrogen to exist for long in the high energy conditions imagined in the neighbourhood of a quasar. Using the National Radio Astronomy Observatory's 140 ft (43 m) radio telescope, the authors of ref. [1] detected a redshifted 21 cm line superimposed on the radio spectrum of 1229-021. The redshift corresponds to the optical absorption redshift of magnesium lines previously reported in ref. [2].

Were this absorption to be intrinsic to the quasar, it must be produced in material ejected at one-third the velocity of light, yet there are no signs of a violent disruptive explosion. An objection to an absorption in a cloud along the line of sight is the embarrassing frequency of such absorption systems (ref. [3]).

The authors suggest additional deep optical photographs, very long baseline interferometric maps of the size and distribution of the absorbing gas, and other related observations be undertaken.

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Universality of Physical Laws

Observations of a quasi-stellar object indicate that physical constants are precisely the same at two comoving points separated by most of the observable Universe. The universal invariance of physical laws appears to be supported by empirical evidence.

There have been few discoveries of 21 cm absorption lines with large redshifts in the radio spectra of QSOs. In ref. [1] the third discovery of a 21 cm redshift system is announced. Observations of the 16.6 mag QSO 1331+170 were planned using the National Astronomy and Ionosphere Center 305 m radio telescope near Arecibo, Puerto Rico. Comparison of optical and radio redshifts would reveal whether certain products of physical constants vary over a look-back time to $z \approx 1.8$ (over 65% of the age of the Universe). Detection of 21 cm and Lyman α absorption in the same gas would enable the spin temperature of a QSO absorption system to be detected, and hence the distance between absorber and QSO could be measured.

The results of the observations on 22 March 1978 and 10 to 13 May 1978 were analysed and the physical implications deduced.

The observed similarity between 21 cm and optical redshifts indicates precise agreement between the ratio of hyperfine to permitted transition frequencies at the absorption epoch and the present epoch. This ratio is determined by a product of three physical constants, and this product must have remained constant over about 1.3×10^{10} years.

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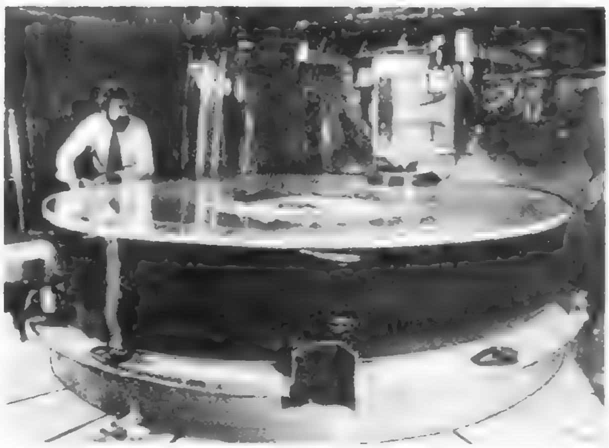

19. SPACE MIRROR. Initial grinding and polishing operations are now underway by the Perkin-Elmer Corporation on the huge primary mirror blank which will become the major optical element of NASA's Space Telescope. The delicate process is expected to take about two years to complete. About 136 kg (300 lb) of glass will be removed during the lengthy grinding and polishing operations. The 2.4 m (8 ft) diameter mirror blank was manufactured by Corning Glass Works, Canton, New York. In its finished state, the mirror will weigh approximately 750 kg (1,650 lb).

National Aeronautics and Space Administration

ORBITS OF SOVIET SPACECRAFT AT 51.6° INCLINATION

By Robert D. Christy

Introduction

A number of Soviet satellites flown in recent years in the 51.6 degree inclination slot have used orbits which produce repeated ground tracks after a few days. The usual reason for this type of orbit is to ensure several opportunities for rendezvous attempts in case of launch delays with the second craft.

Daily Track Repeats

The low orbital periods of the early Soyuz rendezvous flights and their Cosmos precursors gave ground tracks which repeated from day to day, every 16 orbits. The purpose of this was to allow a first orbit rendezvous with the second or third vehicles.

Salyut 1 (1971-32A) used an orbit with daily track repeats to provide launch windows for both Soyuz 10 and Soyuz 11. The nodal period (time between successive northbound equator crossings) to achieve this is 88.5 minutes.

Launched on 19 April 1971, Salyut 1 soon manoeuvred to its stabilised orbit. On 26 April, three days after the departure of Soyuz 10, the orbit had been raised to 89.7 minutes. From then until 2 June, the orbit decayed naturally to 88.5 minutes again and a couple of minor manoeuvres opened a series of launch windows for Soyuz 11. It was the detection of radio transmissions during this operation which allowed the Kettering Group to be waiting for the launch of Soyuz 11 on 6 June, and thus receiving signals as the craft went into orbit nine minutes after launch. After the docking, Salyut's orbit was again raised to prolong its lifetime; none of its later manoeuvres reproduced the daily track repeats.

Higher Orbits

One disadvantage of an orbit of 88.5 minutes is that the height of around 200 km means that costly, fuel-using manoeuvres are constantly needed to avoid rapid decay due to air drag. An orbit giving ground track repeats every day after 15 orbits has a period of 94.4 minutes, much more economical in fuel use but imposing severe penalties on satellite masses.

Salyut 4 (1974-104A), and later Salyut 6 (1977-97A), used orbits with rendezvous launch windows occurring every two days as their tracks repeated after 31 orbits. Some of the manoeuvres of the latter have already been documented[1].

Salyuts 3 and 5 (1974-46A and 1976-57A) operated at heights around 260 km with periods near to 89.8 minutes. During rendezvous operations with the Soyuz ferries, the orbit was slightly lower with an 89.6 minute period; this is the lowest of a series of orbits giving repeated tracks after five days.

The 89.6 minute track repeats every 79 orbits. The next in the series with 78 orbits between repeats has a period of 90.75 minutes. Interestingly, this is one of the orbits used by Cosmos 929 (1977-66A), about which there was much discussion in the Correspondence pages of this magazine during 1978.

Cosmos 929 may have been set up as a rendezvous target for a simulated second launch or may have rendezvoused itself with an imaginary target vehicle. Weight is added to this theory by the fact that it made a series of minor orbit trimming manoeuvres as if station keeping with or approaching another object[2].

Later Developments

Two other recent launches have used orbits with periods around 90.75 minutes and almost identical elements to Cosmos 929. These are Cosmos 1001 (1978-36A) and Cosmos 1074 (1979-8A). Both of these were A-2 vehicle launches, as opposed to Cosmos 929's D-1.

Cosmos 1001, launched on 4 April 1978 was initially discovered to be transmitting on a VHF channel normally used for man related craft. Later, I discovered it to be transmitting CW/PDM signals on the primary Soyuz HF channel. Initially flying in an 89 minute orbit, Cosmos 1001 moved up to its five day stabilised one after six days. After a total of 11 days in orbit, it was commanded to re-enter and was recovered.

Cosmos 1074, launched on 31 January 1978 had the same radio transmission characteristics as Cosmos 1001. Injected into a similar initial orbit, the move up to the stabilised one came three days later. Four days after this, on 7 February a further manoeuvre resulted in a still higher orbit with a period of 92.0 minutes, still repeating its tracks every five days but now at only 77 orbit intervals!

Unlike Cosmos 1001, it was not recovered after a short flight but continued in a slowly decaying orbit until 1 April when recovery took place after 60 days in flight. This mission profile is reminiscent of that of Cosmos 613 (1973-96A), an unmanned Soyuz test.

Cosmos 613 orbited for 60 days from the end of November, 1973 to the end of January, 1974 as a systems test of Soyuz in preparation for the upcoming Salyut 4 long-duration flights. Presumably, it was powered down for most of the mission and then its batteries recharged from a device launched already docked with it to simulate Salyut. This device was probably the large object (1973-96C) left in orbit after recovery. Both Cosmos 1001 (4 catalogued objects) and Cosmos 1074 (5 objects) left debris in orbit after recovery.

Satellite	Date	Perigee (km)	Apogee (km)	Nodal period (minutes)	Notes
Salyut 1	1971 Apr 19	200	210	88.53	Daily track repeats, every 16 orbits.
	Apr 28	251	271	89.67	"Parked" after Soyuz 10 flight.
	Jun 2	200	200	88.44	Stabilised track, prior to Soyuz 11.
	Jun 9	256	264	89.66	Soyuz 11 crew now aboard.
Salyut 3	1974 Aug 27	255	275	89.7	5 day track repeats, every 79 orbits for Soyuz 15 launch windows.
Salyut 4	1975 Jan 17	335	350	91.33	Operational orbit giving track repeats every 2 days, 31 orbits.
Salyut 5	1977 Feb 7			89.6	Track repeats every 5 days, 79 orbits for Soyuz 24 rendezvous.
Cosmos 929	1977 Aug 18	306	330	90.77	30 days after launch, track repeats every 5 days, 78 orbits.
Salyut 6	1978 Mar 3	334	353	91.35	Operational orbit during Soyuz 26/28 occupation, repeats 2 days.
Cosmos 1001	1978 Apr 11	308	319	90.73	Track repeats every 5 days, 78 orbits.
Cosmos 1074	1979 Feb 3	308	322	90.76	Track repeats every 5 days, 78 orbits.
	Feb 7	364	384	91.96	Track repeats every 5 days, 77 orbits.

Orbits of Soviet Spacecraft at 51.6° inclination/contd.

Conclusion
The radio transmissions from the Cosmos 1001/1074 vehicle suggest that it has some relationship with Soyuz; there are several similarities in the telemetry sequence. The Cosmos 1074 flight suggests that a long-duration flight qualification was necessary and indicates the inclusion of new systems.

One possibility is that it is a larger vehicle allowing a return to a three man crew. Interestingly, the Salyut 6 mock-up displayed at the 1979 Paris Air Show has toilet facilities for three men, not two or four as one might expect.

Alternatively, it might represent an unmanned ferry capable of returning materials from an orbiting laboratory to Earth while perhaps leaving its 'orbital module' attached to give the crew more working space or a new instrument cluster. This might explain the object reportedly separated from Cosmos 929 and recovered, and also its dual radio telemetry system. Only time will tell when the Soviets include the new vehicle(s) in an operational system.

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Satellite Orbits at 51.6°: examples of orbits giving repeated ground tracks

THE LAST DITCH

THE APOLLO/LITTLE JOE II ABORT TESTS

By Curtis Peebles

Introduction
A rocket in flight must thread a narrow path of yaw, pitch, roll and acceleration. If the rocket is entrusted with a human crew, they must be provided with a means of escape should the rocket fail. For Apollo, this meant the use of an escape rocket and, of course, it would have to be tested. For this a rocket was developed whose sole purpose was to simulate failure.

Little Joe II
The Little Joe II owes much to the original Little Joe I. Little Joe I was used to test the Mercury abort system. From August 1959 to April 1961, seven Little Joe I vehicles had been flown from Wallops Island, Virginia. Although several were failures, or marginal, they qualified the system [1]. A similar system was now to be used for the Apollo tests.

February 20, 1963, the Manned Space Flight Center announced the awarding of a contract to General Dynamics/Convair for the construction of four Little Joe II boosters, two launch pads at White Sands, New Mexico and launch support.

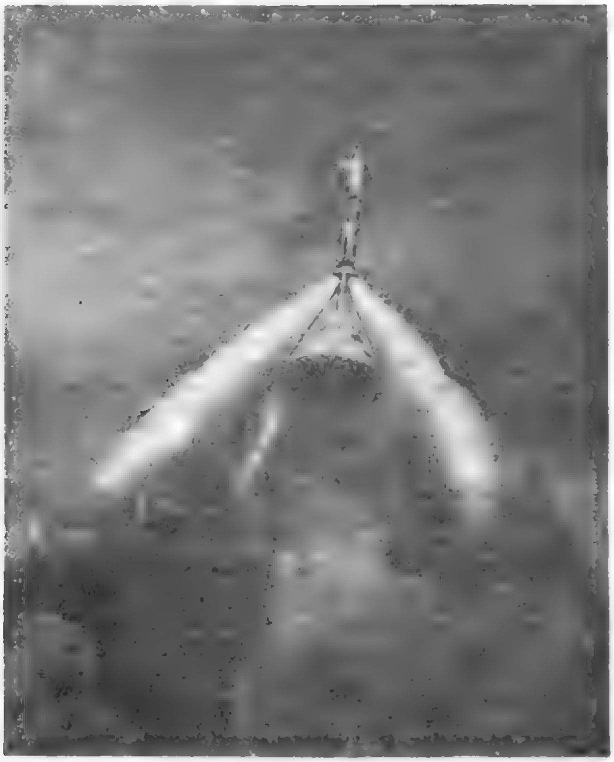
The Little Joe II, like the original North American Aviation Little Joe I, was a simple vehicle. The outer skin was corrugated aluminium; the lower section was built around the thrust bulkhead which supported the various arrangements of Algol 1D and Recruit TE-29 solid fuel rockets and the aerodynamic fins. The forward section supported the payload, the guidance system and the forward ends of the motors. The flight control system used moveable hinged control surfaces at the base of the four fins. For control at low aerodynamic pressures, such as at very low speeds during the first seconds after lift-off and at very high altitudes, it carried a reaction control system. There were two thrusters in each fin housing. They used hydrogen peroxide and had a thrust of 600 lb (273 kg). Its guidance system could use either pre-programming or radio control. The payload was a Boiler Plate Apollo command module and the all important launch escape tower. Despite its simple construction, it was not an overgrown sky rocket. It stood 95 ft (29 metres) and had a diameter of 13 ft (4 metres), approximately as tall as a Mercury Atlas. The peak thrust (7 Algo 1D's fired in a 4-3 sequence) was 860,000 lbf. (390,909 kgf). This could propel a 10,000 lb (4,545 kg) payload to 800,000 ft (243,902 metres).

The first Little Joe II left the General Dynamics/Convair plant in San Diego for White Sands on 15 July 1963 and was ready for launch in late August. It was to be a launch vehicle qualification test, carrying a dummy command module and launch escape system but lacking the hinged control surfaces and reaction control system. It weighed 57,165 lb (25,984 kg).

20. Boiler Plate 6 at White Sands, New Mexico. This capsule was the first to test Apollo's off-the-pad abort capability.
National Aeronautics and Space Administration

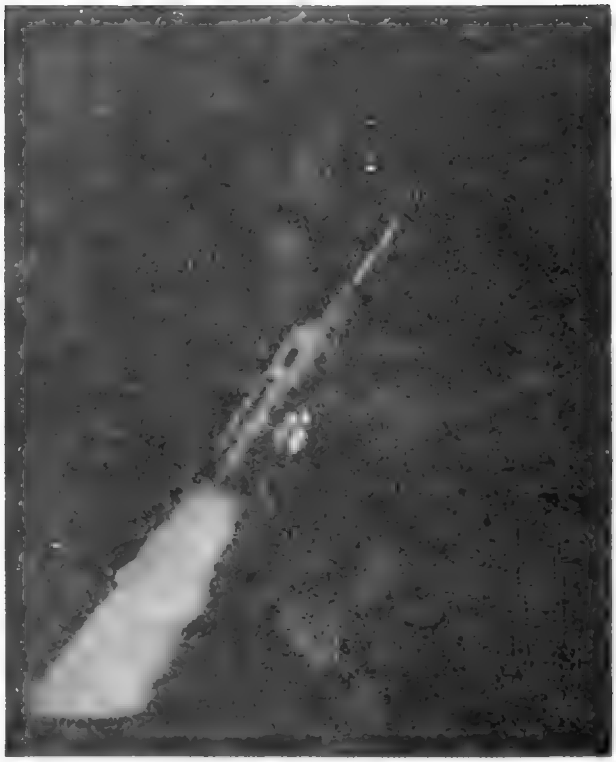
It was simply a test of the Little Joe II's ability to hold together[2].

After a 6 hour and 10 minute countdown, the launch came on 28 August 1963. The six Recruits and centre-mounted Algol rockets ignited and propelled it to the desired 24,000 ft (7,500 metres) altitude, M.1.1 speed, flight path angle and aerodynamic pressure. Three seconds after passing this point, a destruct command was sent but, due to a disconnected primer cord between the initiator and the destruct charge on the Algol casing, it did not explode. It continued past the predetermined point hitting 47,000 ft (14,329 metres) down-



21. The launch of Boiler Plate 6 on 7 November 1963. The roll pattern on the escape rocket and capsule was used to determine the vehicle's stability during flight.

National Aeronautics and Space Administration



22. The flight of Boiler Plate 12. This was the first in-flight test of the launch escape system. Photo 1. The destruct charge has been triggered.

range. 100 seconds of telemetry were recorded. Five of the six test objectives were achieved.

The way was now clear for the next Little Joe II to carry a live escape system. 1 November 1963, the contract was amended; $2,247,174 was added for the construction of two more Little Joe II boosters to be used in high altitude abort tests (over 60,000 ft (18,292 metres). Total cost was now $8,928,637 for boosters, launch facilities and support[3].

On 7 November, the first pad abort test was made. Boiler Plate 6, using a live launch escape system, was fired off a stand. It peaked at 5,000 ft (1524 metres) and was successfully recovered. The test was to determine stability and operational characteristics[4]. The Boiler Plate capsules duplicated the size, shape, weight and centre of gravity of a production command module. They carried telemetry equipment to record engineering flight data. However, they had none of the life support or electronic equipment of a production vehicle.

First Abort Test

The second Little Joe II flight was to follow the same general profile as the first using a similar launch vehicle to test a transonic abort. It carried Boiler Plate 12 and a live launch escape system. It was launched on 13 May 1964 for a brief but eventful mission. At 19,400 ft (5,915 metres), while undergoing transonic buffeting, the destruct signal was sent and it was exploded. The abort rocket pulled it clear. The command module soared to 24,000 ft (7,317 metres). The pitch control motor turned it blunt end forward; the tower jettisoned and the recovery sequence began. The main parachute opened at 7,500 ft. (2,287 metres) but the five ton command module was swinging excessively causing one of the 'chutes to rip free. All the same the command module was able to make a safe, if fast, landing [30 fps (9.15 mps)]. The flight took 7½ minutes and all test objectives were met[5].

Critical test

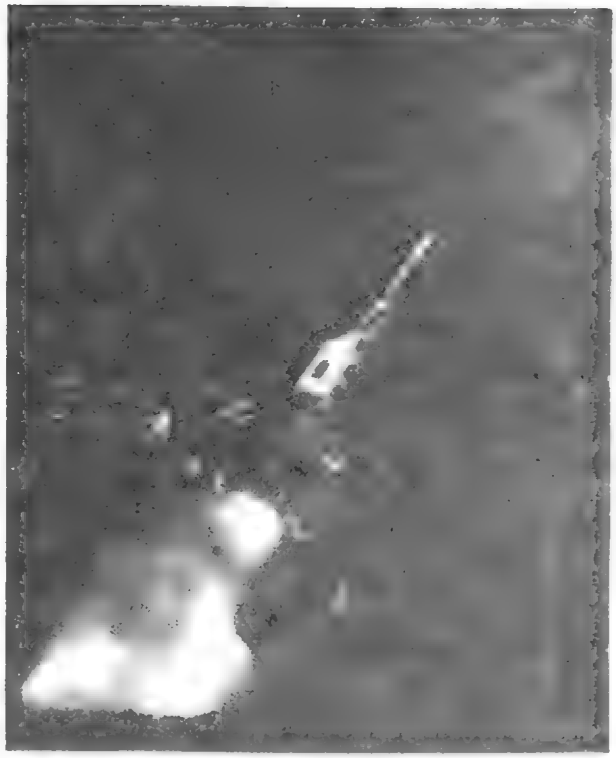
The next Little Joe II test was to simulate a catastrophic failure of the launch vehicle under maximum aerodynamic pressure. There were several changes in the booster; It was the first Little Joe II to use the control surfaces and reaction controls. It, also, used two Algols and four Recruits. This increased lift-off weight to 94,331 lb (42,878 kg) from the 57,930 lb (26,332 kg) of the previous mission. To help stability two pop-out canards were added to flip over the vehicle and stabilize the command module before the tower separated.

The flight was made on 8 December 1964. At maximum aerodynamic pressure, the vehicle pitched up increasing the angle of attack; the aerodynamic pressure was 25% greater than a Saturn 5. Separation came at 32,000 ft (9,756 metres) and it was pulled almost two miles (3.2 km) higher. Boiler Plate 23's recovery was successful. This was the first flight of the boost-protection sub-system which was a conical shell which protected the LM docking equipment and windows during launch[6].

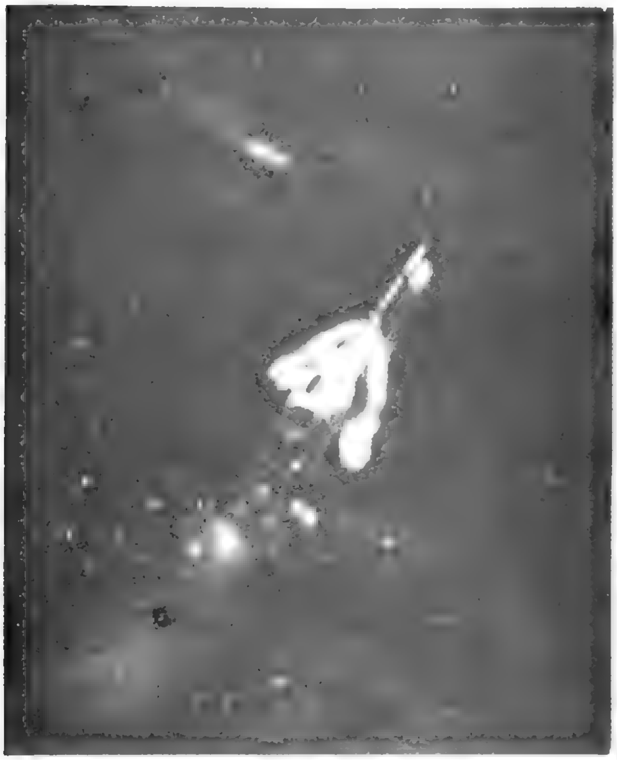
The Real Thing

The fourth Little Joe II test was to be a very high altitude flight to test a vacuum abort and the heat shield's ability to survive an actual re-entry. Abort altitude was selected to be 111,200 ft (33,902 metres) reached 89 seconds after launch. The command module, after separating, was to reach about 184,600 ft (56,280 metres) before descending. The Little Joe II was equipped with six Algol engines. At 177,189 lb (80,540 kg), lift-off weight was the heaviest of any of the Little Joe II's. It was launched on 19 May 1965. Only seconds after launch, the guidance system malfunctioned. The control surfaces deflected hard over causing the vehicle to begin spinning at a very high rate. At 12,400 ft (3,780 metres), the outer skin panels began to disintegrate from centrifugal force. The Algol

23. Photo 2. The outer skin has disintegrated.
All photographs: National Aeronautics and Space Administration

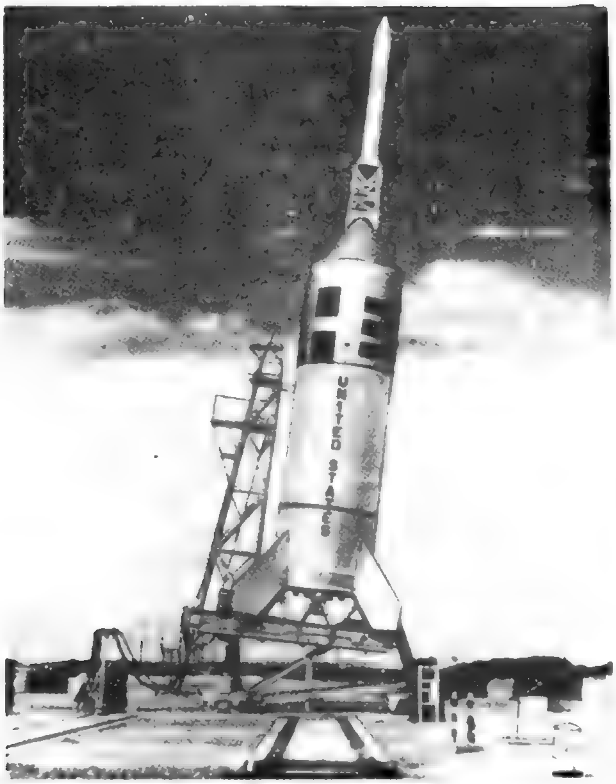


24. Photo 3. The engines begin to falter. Note that in all photos, the command module remains clear of the debris.



25. Photo. 4. The escape rocket and pitch motor ignite.

26. Photo. 5. The launch escape system reaches full thrust and the separation sequence begins.

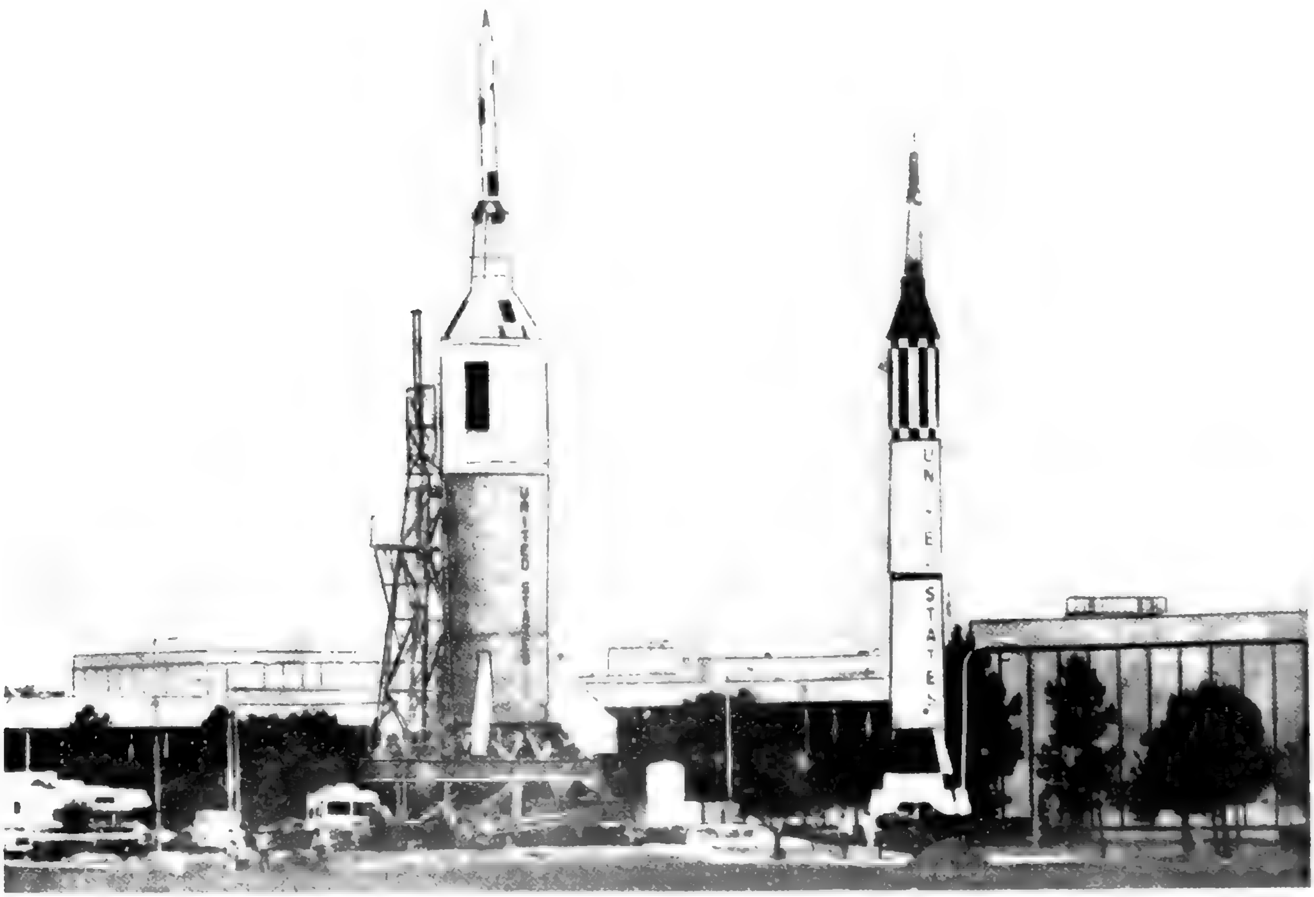


motors separated from the vehicle. The launch escape and pitch motors fired pulling Boiler Plate 22 clear of the now completely broken up vehicle and lowered it to a safe landing. About 25 seconds had elapsed from lift-off to destruction. Apollo project manager, Joseph F. Shea, said later: "Although the prime objective of the high altitude abort tests was not achieved, the launch escape system proved its mettle in an actual emergency which is the purpose for which it was designed"[7].

Coming after such a spectacular event as the Little Joe II break-up, the second pad abort was almost anti-climatic. It was made on 29 June 1965. It used the re-conditioned Boiler Plate 23 previously used on the third Little Joe II flight. Like the first pad abort, it was successful. The "pad" for these tests was a pipe support holding the command module off the concrete. A large corrugated shed protected the command module and launch crew from the summer sun and sandstorms during pre-launch preparations. It was split down the middle and each half could be lowered to the ground.

27. *Left*, the Little Joe II QTV test vehicle. Launched 28 August 1963, it proved the basic systems of the booster. This launch did not carry a live escape system.

28. *Below*, a Little Joe II displayed at the Johnson Space Center. To the right is the Mercury Redstone. The boosters are part of a new park on the west side of the Houston complex. Out of the picture to the left is a Saturn 5.



The Last Ditch/contd.

The Last Little Joe II

The fifth and last Little Joe II was to carry an actual production Apollo CSM designated SC-002. It used five Recruits and four Algol rockets and weighed 139,731 lb (63,514 kg). After sorting out a guidance system problem, an 18 January 1966 launch attempt was scrubbed at T−30 minutes due to heavy cloud cover[8]. Launched on 20 January 1966, it reached an altitude of 57,000 ft (17,378 metres). It pitched up and tumbled end over end, power on, simulating a Saturn control system failure. At 61,000 ft (18,598 metres), three seconds after tumble began, the escape rocket fired. The escape system worked perfectly and Apollo Sc-002 landed gently in the sage brush of White Sands bringing the Apollo/Little Joe II programme to a successful conclusion[9].

Conclusions

Each of the Apollo commanders, thanks to Little Joe II, had the assurance that a twist of the abort handle would accelerate their fragile craft away from a misbehaving booster. Of the four vehicles to carry live escape rockets, all four were successful including the real abort of Boiler Plate 22.

The loss of one of Boiler Plate 12's three main parachutes confirmed the wisdom of designing the command module so that only two 'chutes were necessary for a succssful landing; reconfirmed with Apollo 15.

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SPACE REPORT

SPACE TELESCOPE SERVICING

Underwater tests to evaluate methods and equipment which might be used to service the Space Telescope in Earth orbit have been conducted at NASA's Marshall Space Flight Center, Huntsville, Alabama.

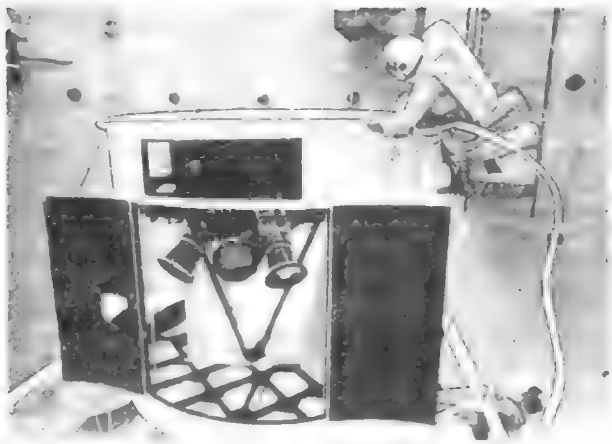
Pressure-suited astronauts from the Johnson Space Center, together with Marshall Center engineers, have been using the huge 1.3-million-gallon water tank facility, known as a Neutral Buoyancy Simulator, which allows a close approximation of a zero-gravity environment. A full-scale mockup of a portion of the Space Telescope was submerged in the tank for the astronauts and engineers to work with in the simulation exercises.

Astronaut Candidates Bruce McCandless and George Nelson first tested the difficulty of unlatching a door to the telescope's star trackers and other components, and determined optimum type and location of foot restraints and hand-holds. The underwater tests were made to decide what modifications, if any, are needed to permit removal and replacement of components in space, and the time required for such tasks.

The Space Telescope, scheduled for launch by the Space Shuttle in late 1983, can be retrieved while in orbit and positioned in the Shuttle Orbiter's cargo bay, where space-suited astronauts can service it as needed.

The mockup used in the Neutral Buoyancy Simulator was the aft shroud portion of the Support Systems Module. Lockheed Missiles and Space Company are developing the module under contract to the Marshall Center which has overall management responsibility.

Other portions were being added to the mockup until a virtually complete Space Telescope is assembled in the tank. The next series of tests will be concerned with insertion and removal of the Telescope's scientific instruments.



29. SPACE DIVER. A pressure-suited astronaut works underwater in a huge tank, called a Neutral Buoyancy Simulator, at NASA's Marshall Space Flight Center. Astronaut Bruce McCandless used the tank to evaluate methods and equipment which might be used to service the Space Telescope in Earth orbit. A full-size mockup of part of the Space Telescope is submerged in the tank.

NASA

AIRSNATCH OF NIKE ORION PAYLOAD

A rocketborne payload launched on board a two-stage Nike Orion sounding rocket was successfully retrieved in mid-air on 11 September 1979 at NASA's Wallops Flight Center. (WFC)

The objective of this diagnostic flight was to study the performance of a prototype payload for subsequent use during the International Ozone Rocketsonde Intercomparison Measurements programme conducted late last year.

Five countries were involved in this ozone intercomparison series – Australia, Canada, India, Japan, and the United States. Measures were made by six Nike Orion, six Super Arcas and six Super Loki rockets. In addition, meteorological rocket, balloon and ground-based measurements were taken into account.

The test payload launched by a Nike Orion reached an altitude of 83 km (52 miles). A unique dual-parachute high altitude decelerator system was flown for the first time. The payload was separated from the Orion motor at an altitude of approximately 60 km (37 miles). It was de-spun and the experiment package ejected from the nosecone assembly; dual decelerators (parachutes) then were deployed at an altitude of approximately 81 km (50 miles).

Using WFC radars, a fixed-wing Sky Van aircraft was vectored to an intercept position and the package was snared in mid-air about 3 km (9,000 ft) above the sea.

Space Report/contd.

ARIANE SUCCESS

The maiden flight of the Ariane heavy satellite launcher from Kourou, French Guiana, on 24 December 1979 was "a total success", according to the European Space Agency. "The functioning of the three stages appears to have been perfectly nominal. The fairing was jettisoned in the planned conditions. The payload separation was nominal and it took place at the planned time... [and] the achieved orbit is very close to the planned orbit."

"The functioning of the Guiana Space Centre facilities and all the down-range stations at Salinopolis, Natal and Ascension was faultless and has permitted continuous tracking of the launcher and the [reception] of telemetry."

The launcher was programmed to deliver a CAT (Capsule Ariane Technologique) into an orbit of 200 × 35 753 km inclined at 17.5 deg. to the equator.

DETECTING CRUSTAL MOVEMENTS

NASA has deployed seven laser satellite-tracking systems in the United States and the Pacific Ocean as part of a continuing global effort to use space technology, over the next decade, to study the strain building up in the Earth's crust and to increase understanding of the causes of earthquakes.

The Earth's crust is believed to contain about a dozen large and almost rigid "plates" which are in constant motion and whose jagged edges continually grind against each other. It is believed that an earthquake occurs when the crustal rocks near the plate boundaries become locked together and are strained beyond their breaking point. The largest number of earthquakes around the globe occur at plate boundaries.

Scientists using historical geological data have been able to infer the average movement of these huge plates over the past few million years. Some plates, like the Africa plate, are believed to be stationary or moving slowly at about one centimetre per year. The Nazca plate off the western coast of South America may be moving at 15 cm (6 in) per year as it thrusts under the South American plate.

A long-term NASA project involving California's earthquake prone San Andreas Fault already is producing interesting results for evaluating the use of satellite laser tracking for the measurement of strain build-up in the Earth's crust.

In California, the North American and Pacific plates are butted together at the San Andreas Fault. As the Pacific plates slide northward, portions of the fault appear to be locked.

The tracking of laser-reflecting satellites in known orbits permits scientists to pinpoint the location of their tracking systems to within three to five centimetres (about 2 in or less).

The laser system flashes a narrow column of light pulses to the overflying satellite. Special reflectors on the satellite collect and return this light directly to its source. It is the precise measurement of the laser beam's roundtrip transmission time – at a speed of 300,000 kilometres (186,000 miles) a second – to the satellite and back that provides the essential information for locating the position of the ground unit.

Six satellites with laser corner cube reflectors are currently being used. The latest of these, the U.S. Laser Geodynamics Satellite, was specifically designed to be a reference point in space for ground lasers.

Corner cube reflectors were placed on the Moon by the Apollo 11, 14 and 15 astronauts. A French-built reflector was implanted by the Russian Luna spacecraft. Lunar laser systems at the McDonald Observatory, Texas; at Haleakala, Hawaii; Australia; and in Wetzel, Germany; have been used to range to the Moon. Other countries, namely the Soviet Union and Japan, have been developing similar systems.

With lasers and microwave methods which use signals from radio stars, such as quasars, it is possible to measure movements of the Earth's crust and thereby analyze conditions under which pent-up strain may be released and cause earthquakes.

Lasers are being installed on Tutuila Island, American Samoa; on Roi-Namur, Kwajalein Atoll in the Marshall Islands; and at Yaragadee in Western Australia. Four mobile lasers are being located in the United States at sites near the Haystack Observatory, north of Boston, Massachusetts; the Owens Valley Radio Observatory, Goldstone, California; and Ft. Davis, Texas.

These lasers join an expanding international network of laser and microwave facilities which complement and extend conventional methods of measuring the Earth's crustal movements.

Satellite laser systems are already in operation in France, Spain, Germany, Greece, Egypt, the Netherlands and England. The United States operates, through the Smithsonian Astrophysical Observatory, laser systems in Arequipa, Peru; Natal, Brazil; and Orroral Valley in eastern Australia. With the addition of the new mobile NASA lasers there will be seven satellite tracking lasers in operation in the United States, including a system at the Goddard Space Flight Center, and a laser operated by the Air Force in Florida.

Other laser systems, which use corner cube reflectors placed on the Moon by the United States and the USSR, are in operation in Texas, Australia and West Germany.

Within the United States, the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, the National Science Foundation, the Defense Mapping Agency and NASA are participating in a joint programme to apply this space technology to a better scientific understanding of the Earth's dynamic processes, including those related to earthquakes.

The NASA portion of this joint programme is conducted through the Crustal Dynamics Project at its Goddard centre.

The coordinated five-agency programme is intended to support the national programme authorized by the "Earthquake Hazard Reduction Act of 1977." Under this act, Congress initiated a broad research programme whose goal it is to reduce the hazards of earthquakes and develop, if possible, the capability to predict earthquakes and possibly to control them.

SPACE-AIDED RESCUE?

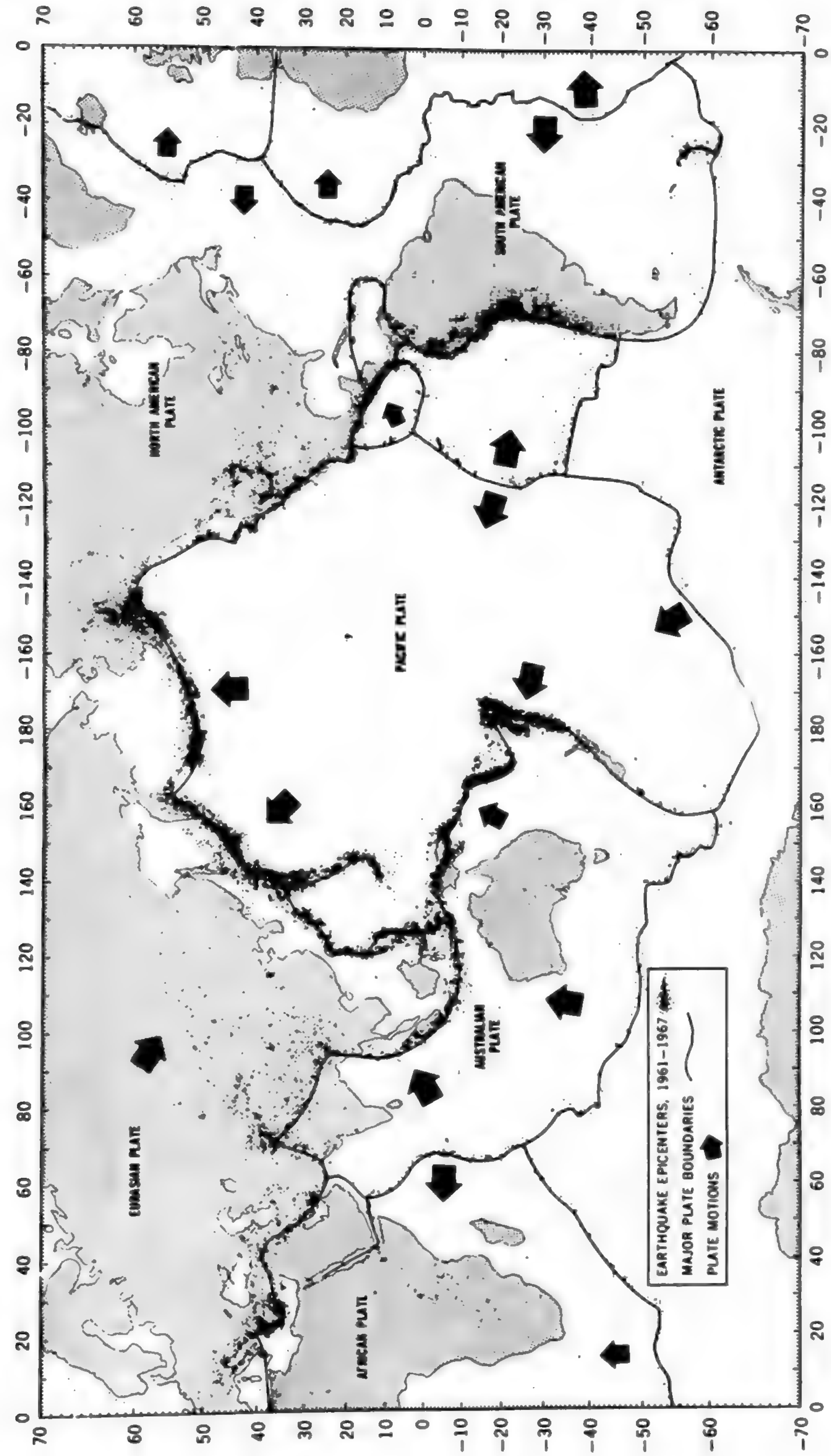
The National Aeronautics and Space Administration, the Canadian Department of Communications and the French Centre National d'Etudes Spatiales, have agreed to evaluate a Satellite-Aided Search and Rescue System. Plans call for a 15-month orbital demonstration and evaluation beginning in 1982.

The trial system is expected to dramatically reduce rescue response time to accident sites by improving distress monitoring coverage, reducing detection time and providing more accurate initial location of distress incidents.

Under the three-party agreement, Canada will provide spacecraft transponders and France will provide receiver/processors to be placed on U.S. National Oceanic and Atmospheric Administration polar-orbiting environmental satellites. The United States will modify the satellites, provide satellite antennae, integrate and launch the satellites and develop experimental emergency beacons for aircraft and ships to be used with satellites.

The system will operate with the newly developed beacons and with existing experimental emergency locator transmitters and marine emergency position-indicating radio beacons carried by aircraft and ships. All three countries will provide ground stations and conduct demonstration and evaluation activities including performance tests and simulated search and rescue demonstrations.

The satellites will "listen" on the 121.5 MHz and 406 MHz



MAJOR TECTONIC PLATES

30 Earthquake epicentres, major plate boundaries and plate motions (see 'Detecting Crustal Movements').

emergency frequencies used by ships and aircraft. Travelling in orbits over the poles, one satellite can cover the entire globe every 12 hours.

Within minutes after an initial alert is received, a fix, pinpointing the emergency site within 20 km (13 miles) is produced by ground computers.

The information is flashed to rescue coordination centres, notifying them that an emergency has occurred and pinpointing the site.

The satellite system measures the varying Doppler shift in the frequency of the experimental emergency locator transmitter or the marine emergency position-indicating radio beacon signal as the satellite approaches, passes over and then moves away from the crash or emergency site. (The high speed of the satellite produces an apparent increase in the frequency of the ground signal the spacecraft receives while it approaches and a similar decrease as it moves away from the source of the emergency signals.)

Negotiations are under way among the parties to the satellite agreement and the Soviet Ministry of Merchant Marine for possible cooperation with the Soviet Union. The Soviet Union is planning a similar system for its own spacecraft, with a view to establishing a system compatible with the United States, French and Canadian one. The addition of the Soviet spacecraft would enhance the system's alert and response time.

If successful, the experimental project could eventually lead to the establishment of an operational international satellite-aided search and rescue system to save lives of crash or marine emergency victims as well as significantly reduce the costs of prolonged search operations.

HUGE ENERGY BURSTS

Could the Milky Way galaxy – in which our solar system is but a tiny fragment – change from its quiet, millpond existence into a turbulent, churning dynamo, expelling matter and energy billions of miles into space? Has it done so in the past? Will it happen again?

Dr. Minas Kafatos of George Mason University, Fairfax, Virginia, and NASA's Goddard Space Flight Center, says such events are possible if his theory that massive rotating black holes, millions of times more massive than the Sun, are causing the enormous release of energy from the centres of active galaxies and quasars.

Quasars themselves are baffling objects to astronomers. They emit vast amounts of energy and are belived to be the most distant objects observed, some possibly as far as 10,000 million or more light-years away, at the very edge of the observable Universe.

Recently, radio observations by Drs. Kafatos, R. W. Hobbs, S. P. Maran and L. W. Brown of Goddard, have shown that the central component of Cygnus A, a "nearby" radio galaxy some 1,000 million light-years away, which puts out as much energy in radio waves as a 100,000 million Suns would emit in visible light, is similar in many respects to quasars.

The theory that there are massive holes at the centres of active galaxies or quasars is not new, but the concept that the black holes powering the active nuclei are rotating is new.

What Kafatos says is that it is theoretically possible to extract energy from the region surrounding the black hole, called ergosphere, by processes known in the Theory of General Relativity as "Penrose Processes." According to this idea, matter falling toward the surface of the rotating black hole can break up, with one portion being injected into the black hole at half the speed of light and never emerging while the other portion would fly out with more energy than the total object had when it entered the ergosphere.

The energy it gains is transferred from the rotational energy of the black hole. In effect, the matter ejected gains energy by slowing down the spinning of the black hole. The spinning process depends critically on the black hole rotating rapidly enough.

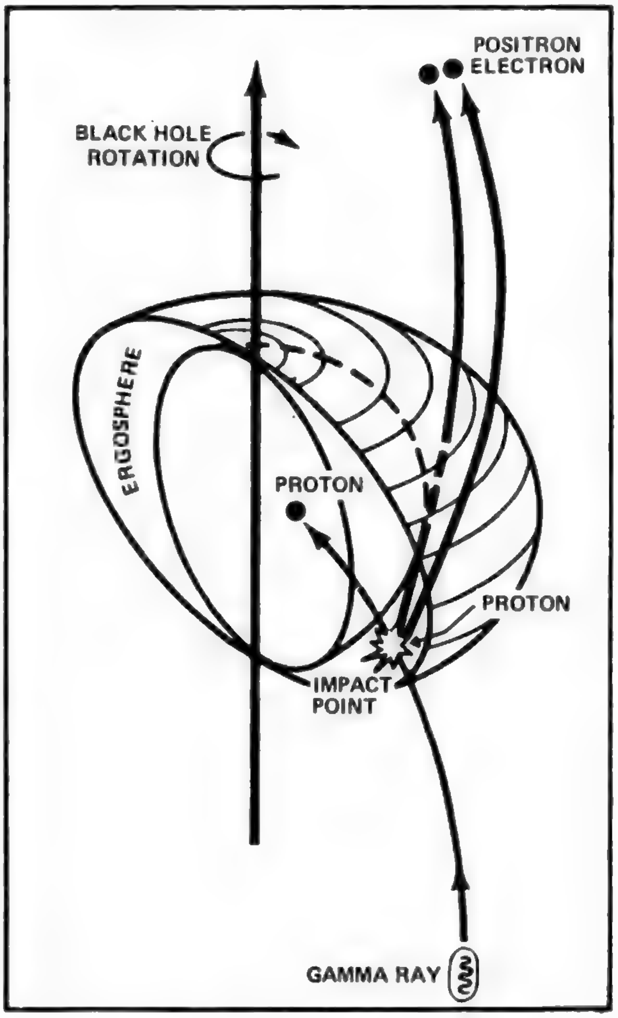
Kafatos and Darryl Leiter of George Mason University recently studied Penrose Processes involving elementary particles in the ergospheres of what they believe are rotating black holes. What is required in these processes is a supply of very high energy light waves, known as gamma rays, entering the ergosphere.

The results of the theory proposed by Kafatos and Leiter can be summarized as follows: the gamma rays enter the ergosphere, slam into protons and are turned into electrons and positrons. The two new particles then are picked up by the rotation of the black hole. The proton is sucked down the black hole, never to return, while the electron and positron are ejected by the rotation with much more energy than the original gamma ray possessed.

The details of the theory are under study by Kafatos. The Penrose Processes are continuous, with matter and gamma rays bombarding the swirling hole, detaching energy and breaking out of the galaxy.

The gamma rays are formed by the very hot accretion disk of swirling gases that form around the hole. However, there must be sufficient gaseous mass available in the galaxy to continue the processes, otherwise, the black holes, like gigantic vacuum cleaners in space, would empty the centre of the galaxy of the material necessary to cause violent activity in the galaxy.

"Energy extraction would become inefficient once the gas



31. Rotating 'Black Hole'.

falling into the black hole becomes depleted or the spin of the black hole is reduced," says Kafatos. "That's why we observe the most violent events in the distant past, thousands of millions of light years away from Earth, because in those early days of the Universe there was more gaseous mass available."

Three active galaxies, including a radio galaxy and quasar 3C273 (famous because of its brightness and variability) have been examined by Kafatos via data received from radio astronomy telescopes and from NASA's Small Astronomy Satellite 2, launched in 1972. The Kafatos studies indicate that the theory of the Penrose Processes may be correct. All of these galaxies emit a majority of their energy in gamma rays, a surprise in view of the fact that it is very difficult to produce gamma rays in nature. In addition, the three active galaxies examined radiate radio waves as predicted by the theory.

Kafatos expects the theory can be confirmed in the early 1980s when the NASA Gamma Ray Observatory is placed in orbit by the Space Shuttle. Present spacecraft are not sufficiently advanced to "look" far enough into space at other active galaxies or quasars.

The theory also explains the relative inactivity of nearby normal galaxies. But even they could flare up if sufficient gaseous material were found, for example, by a chance breakup of a cluster of thousands of stars near the black hole. The gaseous material could then be drawn into the middle of the galaxy by the massive black hole which would cause the nucleus of the galaxy to explode with activity. Such an event could happen to any normal galaxy containing a massive black hole.

"Maybe our own Milky Way galaxy flared up like that millions of years ago as a result of such a chance event. In fact, it could flare up again in the future," Kafatos says.

NASA SEEKS INDUSTRIAL PARTNERS

Guidelines have been set up for innovative joint ventures which will make it easier for American companies to use the environment of outer space for commercial manufacturing.

NASA is offering industry "equity partnership ventures" in the use of its Space Shuttle transportation system, technical advice, data, equipment and facilities. Administrator Robert A. Frosch calls the action "neccessary and proper to achieve the objective of national technical superiority through joint action with US domestic concerns.'

The guidelines are intended to facilitate the entry of American industry into an area traditionally left to the Federal government because of the high technology and high economic risks involved.

Space flight has been virtually untapped as a unique laboratory for materials processing. Ground-based research, however, as well as experiments in the Apollo, Skylab and Apollo-Soyuz flight programmes and with sounding rockets, showed that materials in a liquid state behave much differently in the near weightlessness of space than on Earth, and that this behaviour in space can be used to advantage in preparing a number of substances. For instance, there are no convection forces to make differing fluids segregate and no need for containers to hold materials as they are cast.

As a result of extensive materials-processing research already conducted on Earth, areas of potential commercial interest in space are: semiconductors – electronics, computers; infrared detectors – medicine, spacecraft; nuclear detectors – medicine, spacecraft; solid state lasers – communications, optics; microwave devices – communications, solar power; castings, alloys, composites and metal foams – metallurgy, machine tools; blood fractionation, purified hormones, enzymes, vaccines, products of live cells, cell culturing – medicine.

The joint venture programme envisages a government-industry relationship in which the risk capital and technical know-how of industry works in concert with the resource capabilities of NASA to develop and enhance US commercial leadership in the field of materials processing.

To this end, NASA is providing a number of incentives to American industry, including:

- Flight time on the Space Transportation System;
- Technical advice, consultation, data, equipment and facilities;
- Joint research and demonstration programmes;
- Proprietary information protection.

American companies desiring more information on NASA's joint venture programme should write to: Dr. John Carruthers, Director, Materials Processing in Space, Code EM-7, NASA Headquarters, Washington, D.C. 20546.

MARECS C CONTRACT

British Aerospace Dynamics Group, as lead contractor for the MESH Consortium, has received an order worth £15 million from the European Space Agency to build the third maritime communications satellite, MARECS C.

The first MARECS is scheduled to be launched in 1980 to provide improved communications between ships at sea and shore stations.

The three MARECS satellites are being offered by ESA to the newly formed INMARSAT Organisation for use in a world wide system of operational maritime satellites.

COMMUNICATIONS EXPERIMENT ENDS

A historic U.S.-Canadian project to advance communications via satellite ended last October when the world's most powerful space communicator, the Communications Technology Satellite, relayed video and voice signals for the last time. More than 160 United States experiments were conducted with the satellite over a three-and-a-half-year period, ranging from business teleconferences – designed to save busy executives time and travel expenses – to emergency use during a disastrous 1977 flood and discussions of concern to the Indian communities involving tribal participants in Montana and New Mexico and government officials in Washington, D.C.

The highly instrumented portable ground terminal was transported some 100,000 km (62,000 miles) in support operations for the satellite which is in Clarke (geostationary) orbit.

The technology satellite was a joint project of NASA and the government of Canada's Department of Communication. NASA's Lewis Research Center, Cleveland, managed the U.S. experiments which ceased in June last year. Canada designed and built the satellite which for the first time operated in the 12 to 14 gigahertz frequency band. The Lewis centre also furnished the solar-powered travelling-wave transmitter which has 10 to 20 times the broadcast power of current communications satellites. NASA did the pre-flight environmental testing on the spacecraft and launched it from the NASA Kennedy Space Center in Florida on 17 January 1976.

Daniel J. Shramo, director of Space Systems and Technology at Lewis, cited the satellite's accomplishments:

"It's taught us that new frequency bands can be tapped successfully and that advanced technology such as embodied by the travelling-wave transmitter can bring startling advances in broadcast communications," he said.

"We have demonstrated that low-cost Earth terminals may indeed be substituted for conventional big-dish antennae when sufficient signal-sending power is available from the spacecraft to provide clear, bright, two-way television between distant parts of the country and even between continents."

Among the satellite's more complex experiments was one in September 1978 involving transmissions between Buenos

Aires, Argentina, and United Nations Headquarters in New York City.

Pictures and voices of people attending a Buenos Aires U.N. conference on technological cooperation among developing countries were fed via the satellite to the NASA portable ground terminal stationed just outside U.N. Headquarters. Remarks were then simultaneously translated into each of the five official U.N. languages and immediately relayed back to Buenos Aires via the satellite, to be picked up in the delegates earphones.

The satellite also carried high-speed transmissions of documents used to illustrate the Buenos Aires presentations. These were translated and beamed back to the Argentinian capital the following day.

The experiment, hailed as a milestone, underlined both the feasibility and desirability of holding international conferences via satellite.

More commonly, the satellite, orbiting stationary over the equator, processed "town meeting" exchanges between Congressional members and their constituents, exchanges between university lecture halls,and student assemblies several states away and exchanges between teaching hospitals and medical assemblies separated by thousands of miles.

The satellite is expected to be the forerunner of commercial broadcasting satellites of the future that will beam television and data directly into homes and business offices.

We shall be reviewing the growing market for domestic communications satellite services in a future issue. Ed.

'OFF THE PEG' SHIP TO SHORE COMMUNICATIONS

A European manufacturer, Dornier System GmbH, is now offering a complete, satellite based, maritime communications package, writes Robert Christy. Developed in conjunction with Siemens AG, the Dornier equipment is designed initially for use with Comsat General Corporation's Marisat system.

Three of these vehicles were placed in geostationary orbit by NASA during 1976, for a group of US companies headed by Comsat General. The three satellites are providing an almost global service from locations at longitudes 15° west, 176.5° east and 73° east respectively. Later, capacity will be increased by the launch of the European MARECS (MARitime European Communications Satellites).

The Dornier package can be used with both Marisat and MARECS. It consists of an above-deck parabolic antenna and receiver system, and below decks, a control and operating station.

The antenna, a 1.45 m diameter paraboloid, operates in the 1.5-1.6 GHz band. Weighing 310 kg including its protective radome, it has a computer controlled three-axis stabilisation system, which can cope with a ± 35° roll, a ± 15° pitch and a turning rate of up to 6° per second. It is designed to cope with a wide range of ocean environments over a temperature range from −40° to +65° Centigrade. Below decks is housed the control terminal and operator's console. The terminal itself is designed to fit a standard 19 in (48 cm) equipment rack. The console consists of two way teleprinter and facsimile transmission equipment, as well as normal telephone links.

The main ground stations in the Marisat system are at Southbury, Connecticut and Santa Paula, California. Through these, vessels can be assigned individual communications channels with connections into normal international telephone or telex services, including direct dialling of calls.

As well as the actual communications equipment, Dornier is also preparing to offer computer based data management programmes. One advantage of the Marisat/MARECS type system is that vessels can be in contact with their owners for the full 24 hours of each day, and as a result have instant access to up-to-date information, allowing increased efficiency of fleet management. Before the advent of satellite maritime communications, shipping communication used short wave radio which is very interference prone and connections are unreliable. As a result, contacts could not be guaranteed and consequently, the most effective use could not be made of a company's vessels.

32. LOCKING ON. Earth sensors, devices that help maintain a satellite in proper relationship to the Earth, get white glove treatment during a pre-flight check at Hughes Aircraft Company in California. The sensors are aboard Westar 3, a satellite owned by Western Union to provide U.S. customers with voice, video and data communications. It was launched from Cape Canaveral on 10 August 1979. Hughes built three Westars for Western Union, two of which were placed in Clarke (geostationary) orbit in 1974

SATELLITE DIGEST–134

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. A detailed explanation of the information presented can be found in the January, 1979 issue, p. 41.

Continued from the January issue

Name, designation and object number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch site, launch vehicle and payload/launch origin
Cosmos 1128	1979 Sep 14.64	Cylinder +sphere	6 long?					Plesetsk
1979-81A 11529	13 days (R) 1979 Sep 27	+cylinder-cone? 6000?	2.4 dia?	174	330	62.82	89.55	A-2 USSR/USSR
HEAO 3 1979-82A 11532	1979 Sep 20.227	Hexagonal cylinder 3150	5.8 long 2.4 dia	484	500	43.60	94.38	ETR Atlas Centaur NASA/NASA (1)
Cosmos 1129 1979-83A	1979 Sep 25.65 20 days (R) 1979 Oct 15	Cylinder +sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	218	377	62.82	90.45	Plesetsk A-2 USSR/USSR (2)
Cosmos 1130-1137 1979-84A to H	1979 Sep 28.52 10 000 years	Spheroids? 40?	1.0 long? 0.8 dia?	1400 1410 1429 1441 1455 1465 1472 1472	1482 1486 1483 1485 1486 1493 1501 1519	74.03 74.04 74.02 74.05 74.01 74.02 74.03 74.03	114.69 114.83 115.02 115.18 115.35 115.53 115.70 115.90	Plesetsk C-1 USSR/USSR (3)
Cosmos 1138 1979-85A	1979 Sep 28.52 14 days (R) 1979 Oct 12	Cylinder +sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	199 362	373 409	72.86 72.86	90.24 92.31	Plesetsk A-2 USSR/USSR (4)
1979-86A	1979 Oct 1 indefinite				geostationary orbit			ETR Titan 3C DoD/USAF (5)
Ekran (4) 1979-87A	1979 Oct 3.72 indefinite	Cylinder +2 panels +antenna array 2000?	5 long? 2 dia?		geostationary orbit			Tyuratam D-1-E USSR/USSR (6)
Cosmos 1139 1979-88A 11564	1979 Oct 5.48 13 days (R) 1979 Oct 18	Cylinder +sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	201	333	72.86	89.49	Plesetsk A-2 USSR/USSR
Cosmos 1140 1979-89A	1979 Oct 11.69 120 years?	Cylinder? 750?	2 long? 1 dia?	779	804	74.07	100.75	Plesetsk C-1 USSR/USSR
Cosmos 1141 1979-90A	1979 Oct 16.51 1200 years?	Cylinder +boom 700?	3 long? 2 dia?	960	1001	82.95	104.76	Plesetsk C-1 USSR/USSR (7)

Supplementary notes:
(1) Third, and last, High Energy Astronomical Observatory. Unlike its two predecessors, the new satellite is measuring cosmic rays and gamma rays, rather than X-radiation.
(2) International co-operative biosatellite like Cosmos 782 and Cosmos 936. Contributing nations were the USSR, Czechoslovakia, France, the GDR, Hungary, Romania, Poland and the USA. The payload included experiments in radiation medicine and the development of embryos in weightlessness.
(3) Multiple launch of eight small craft, possibly for military communications. An orbit is shown for each satellite.
(4) Orbital data are at 1979 Sep 29.3 and Oct 5.0.
(5) US military satellite, possibly for early warning purposes.
(6) Domestic TV relay satellite, located above 99° east longitude.
(7) Navigation satellite.

Amendments: Satellite Digest – 127 (June 1979), supplementary note (9) refers to Intercosmos 19. There is no note (10).

BOOK REVIEWS

Catalogue of the Universe
By P. Murden *et al* Cambridge University Press. 256 pp. 1979. £9.50.

This is a particularly interesting new book on astronomy for the general reader, filled with many unique photographs of stars and galaxies. Basically, it is a selection of illustrations with descriptive texts on a number of celestial objects, many well known, others less so.

The book is divided into three main sections, i.e., galaxies, stars and nebulae and the Solar System, ending with several appendices.

The section on galaxies is sub-divided into clusters and "normal galaxies", practically all consisting of the photograph of each object referred to with a short descriptive text. Most of the pictures appear to be of relatively recent vintage, borne out by the fact that many were taken by David Malin who developed a new technique to bring out the delicate structures of many of the gas clouds of the Milky Way.

Although a number of individual stars receive their own descriptive text, the bulk of the book is, clearly, concerned with the "great beyond", with the Solar System bringing up the rear, so to speak.

In no sense is this a general book on astronomy: it is primarily concerned with describing specific celestial objects.

About 100 of the photographs were taken with Britain's new telescope in Australia, showing objects never before photographed in such fine detail.

This is a volume very much to be recommended.

L. J. CARTER

34. NCC 2207 (Anglo-Australian Telescope) p. 29 'Catalogue of the Universe'.

The Society has just completed what has probably been its most successful year from an advertising point of view. All of these endeavours have been reflected in an increased membership and enhanced prestige.

Press

The publicity following publication of the Daedalus Report has been widespread and continuing, both in the technical and popular press, an unusual example being the article which appeared in *Space World* for June/July 1979 but which had been reproduced in turn from *Commercial Space Report*. Daedalus has also been featured on radio and TV and plans are currently being discussed to include reference to it in a documentary film.

The article in *SPACEFLIGHT* on "Space Recommendations to the European Parliament" aroused interest in ESA itself: substantial excepts appeared in the *Staff Association Committee News* of the European Space Operations Centre.

This was additional to the work of individual members who have made mention of the Society in articles and letters wherever practicable. A good example of the latter appeared in the magazine *Stamp Collecting* where practically a whole page was devoted to the special envelopes prepared during the 1961 European Space Symposium, the page of letters being emblazoned with a reproduction both of an envelope and the Society's new logo. The Editor was able to include only a selection of the letters received on the subject.

The Society also issued a Statement to other member societies on the move of its new offices, asking them to bring this to the attention of their members and enclosing a selection of photographs by way of illustrations. Very useful publicity resulted.

New Society Publication

It is impossible to say what the effect of *High Road to the Moon* will have, but it is very likely that it will receive just as much publicity as Daedalus. This will be a unique book, reproducing many of the visionary drawings and illustrations of the late R. A. Smith which recorded the Society's original ideas and discussions on Lunar Exploration. The pictures depict ideas on orbital rockets, space probes, craft to take men to the Moon and lunar exploration. It provides a visual account on how pioneers imagined things would be, and how they actually were. It goes beyond the present, for man's involvement with the Moon is not yet finished. This book will be a *must* for every member.

References in Books by Members

Julian Popescu led the way with reference to the Society in his new book on *Soviet Space Exploration*. An advertising leaflet and a special press release put out by the publishers, as well as the book jacket itself, all contained excellent references to the Society. Ken Gatland's new book, *The Space Shuttle Handbook*, followed suit.

This is an area where author-members can play an outstanding part.

Membership Leaflets

David Holmes produced a fine leaflet advertising "The Origin and Evolution of the Universe", copies of which have been made available for display by Members at a number of meetings. Additionally, a new membership promotion leaflet by Keith Page, featuring Daedalus, has also just been prepared. Copies of both leaflets are available to any members who can arrange for them to be displayed. (For speed of reply, please enclose a foolscap reply paid envelope and indicate the number of leaflets required).

Exhibitions

Over 600 copies of *SPACEFLIGHT* and membership forms were distributed at the 37th World Science Fiction Conference at Brighton in August, due to the efforts of David Hardy, Matt Irving, Gerry Webb and Adrian Perkins. The material was displayed on a number of stands, with Matt much to the fore with the Society's new T-Shirt, which attracted many admiring glances. Adrian Perkins also scored a bit of one-upmanship by reproducing "Just Good Friends" by Alan Farmer from *SPACEFLIGHT*, which was particularly apt for this conference. Besides this, the Society advertised in the conference programme.

Advertising also took place in other events which could attract new recruits, such as Air Shows. Activities of this sort are first rate at promoting the Society.

Conferences

Conferences and courses organised by members themselves, sometimes at universities or polytechnics under the aegis of some educational body, are excellent recruitment areas for new members. Usually a group of lectures is involved, with heavy reliance on the Society for film support and the provision of literature, e.g. copies of magazines and application forms. The result from such intensive courses is very similar to the direct member-solicitation of new recruits. Experience, time and time again, has shown this to be the activity most worthwhile.

Best of all, of course is the one-to-one relationship, i.e., where one member personally introduces another. This is worth its weight in gold!

In the Classroom

Bundles of publicity material were made up for despatch to teachers interested in space for them to use in classroom discussions. Quite a lot of work was involved in this and the cost was relatively high, but it has always been the policy of the Society to try to reach the rising generation within the limit of its funds. One surprising indication of the Society's past work took the form of a cable from the United Nations asking for copies of the student leaflet published by the Society entitled "How Rockets Work". These leaflets were issued as giveaways and have been out of print for many years now. It was interesting to learn that they are still being sought after.

Films

Another useful contribution took the shape of specially-prepared leaders to be inserted in the front of films available for loan. These depicted the Society's name and address over a reproduction of its logo. Borrowers of films are always asked to acknowledge the Society's film service but rarely do so. The new leaders will now ensure that the name of the Society is brought to the attention of the audience every time from now on.

Our new Advertising Sign

Last, but not least, was the erection of the Society's name in large white characters and visible to commuters on the Southern Rail section (20,000 plus daily) as well as to users of the busy road junction at Vauxhall Cross. It quite clearly put the Society on the map. Everyone, so far, seems to be very pleased with it.

Unfortunately, owing to lack of funds, the Society's motif could not be added, though permission for this had been received from the Planning Authorities. This must await another day.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 27/29 South Lambeth Road, London SW8 1SZ

Correspondence and manuscripts intended for publication should be addressed to the Editor, 27/29 South Lambeth Road, London SW8 1SZ.

Opinions in signed articles are those of contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Study course
Title: **FUTURE OBSERVATION IN COSMOLOGY**
by Dr. C. D. Mackay
To be held in the Golovine Conference Room , Society H.Q., 27/29 South Lambeth Road, London, SW8 1SZ on **6 February 1980**, 6.30-9.00 p.m. **(Please note revised date)**
Registration is necessary. For further details apply to the Executive Secretary.

Visit
A tour of the Astronomy and Space Galleries of the Science Museum, Exhibition Road, London, S.W.7, accompanied by Dr. John Becklake, will take place on **12 February 1980**, commencing at 6.30 p.m.

Admission (restricted to members only) will be by ticket available from the Executive Secretary on request enclosing **a reply-paid envelope.**

17th European Space Symposium
Theme: **ASTRONAUTICS IN THE NEXT 50 YEARS**
A three day meeting to be held at the Royal Commonwealth Society, London, W.C.2. from **4-6 June 1980**, sponsored by the BIS, AAAS, AIDAA and DGLR and co-sponsored by EUROSPACE.

Offers of Papers are invited. Please contact the Executive Secretary for further information.

Registration is necessary. Copies of the programme will be available in due course.

31st IAF Congress
The 31st Congress of the International Astronautical Federation will be held in the Takanawa Prince Hotel, Takanawa, Minato-ku, Tokyo, Japan from **21-28 September 1980**.

Members of the Society intending to present papers are asked to notify Dr. L. R. Shepherd, Chairman of the BIS International Liaison Committee at Society H.Q. as soon as practicable. Further information on the Congress will be published as it comes to hand.

ASTRONAUTICS HISTORY
Readers are reminded that the first **ASTRONAUTICS HISTORY** Issue of JBIS - dated December 1979 - is now available. Edited by Mitchell R. Sharpe of the Alabama Space and Rocket Center, it covers an interesting variety of topics:

The Use of the German V-2 in the United States for Upper Atmosphere Research, by S.A. Curtis.
The Creation of NASA, by Brian R. Page.
From the S-IV to the S-IVB: The Evolution of a Rocket Stage for Space Exploration, by Roger E. Bilstein.
Project Ranger: Forging a New Era in Space Science, by R. Cargill Hall.
Science and Manned Spaceflight: The Skylab Experience, by W. David Compton.
The Rocket in India from "Ancient Times" to the 19th Century, by F.W. Winter.
Shoeburyness: A Centre of Britain's Rocket Testing in the 19th Century, by Matthew P. Windibank.

Further contributions to this series are being sought and potential contributors are asked to write directly to: Mr. Mitchell R. Sharpe, Alabama Space and Rocket Center, 2215 B Jonathan Drive, Huntsville, Alabama 35810, United States of America.

BACK COPIES OF "SPACEFLIGHT" AND "JBIS"

Members who lack particular issues or new members seeking to expand their collection of Society magazines might like to know details of current availability of back issues.

Those which can be supplied immediately from the Society's stock are listed below:-

	Price	
SPACEFLIGHT	*Sterling*	*US Dollars*
(i) 1977 issues - complete	£10.00	$22.00
(ii) 1978 issues - complete	£10.00	$22.00
JBIS		
(i) 1977 (lacking March issue)	£ 9.00	$20.00
(ii) 1978 issues - complete	£10.00	$22.00

Individual copies are £1.00 ($2.50) each, post free, from HQ.

The contents of individual issues of *JBIS* have already been listed in *SPACEFLIGHT* but are summarized as follows:-

	1977	*1978*
Interstellar Studies	3	4
Space Communications	2	1
Space Technology	3	3
Remote Sensing	1	2
Space Science	1	-
Special Issues:-		
Space Colonization	1	-
Planets and Life	-	1
Spacelab Experiments	-	1
	11	12

A batch of early (small size) issues of *JBIS*, covering the period 1947-1950, together with issues of *Pacific Rockets* are also available - all of which are now of considerable historic interest. There are no complete runs but issues will be sent, subject to availability, at the rate of 20 different copies for £10.00 ($22.00).

Reprint Volumes
Most of the earlier years can be obtained as follows:-
(a) **SPACEFLIGHT** from Swets & Zeitlinger, Backsets-Department, Heereweg, 347C, P.O. Box 810, 216 SZ Lisse, Holland.
(b) *JBIS* from Kraus Reprint Corporation, 16 East 46th Street, New York, N.Y. 10017, USA.
Enquiry should be made to each Publisher beforehand for details of current prices and availability of volumes.

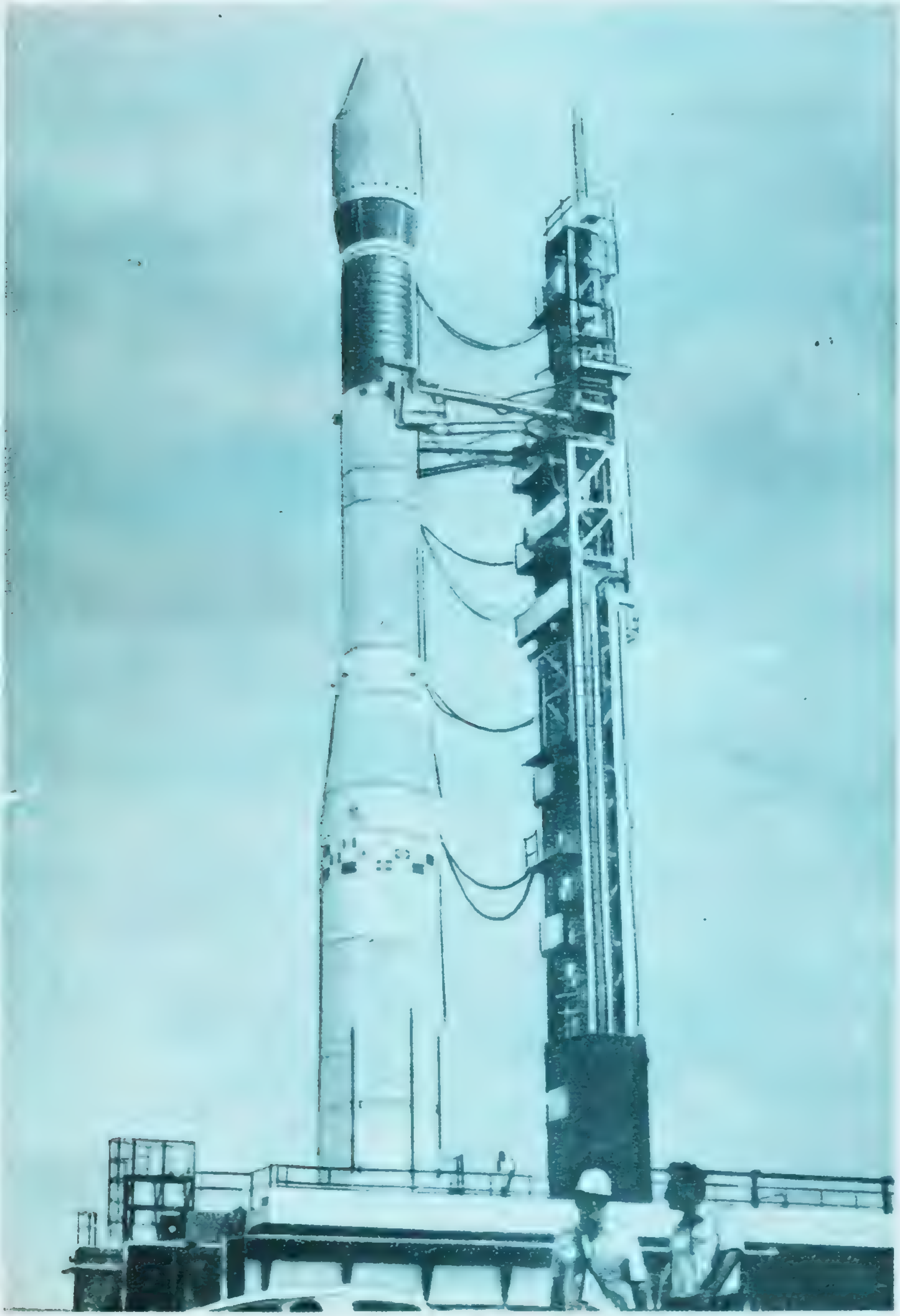
Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published for The British Interplanetary Society Ltd., (No. 402498) by Space Educational Aids Ltd., (No. 741211). Registered Office, 27/29 South Lambeth Road, London, SW8 1SZ, England.

ISSN 0038-6340

SPACEFLIGHT

VOLUME 22 NO. 3 MARCH 1980

Published by The British Interplanetary Society



SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 NO. 3 MARCH 1980 *Published 15 February 1980*

Editor
Kenneth W. Gatland, FRAS, FBIS

CONTENTS

COVER

ARIANE. Europe's hopes of gaining independence in satellite launching depend on the success of the Ariane launcher. The maiden flight from Kourou, French Guiana, on 24 December 1979 succeeded in launching a CAT (Capsule Ariane Technologique) plus ballast into an orbit of 201 x 36 003 km inclined at 17.55 deg to the equator, very close to the prescribed trajectory. Much of the credit for the accuracy of the orbit is due to British manufacturers who supplied vital components of the guidance system. Britain, however, misses out badly on the construction of the launcher. France makes the biggest financial contribution of 63.87 per cent and naturally has the lion's share of the contracts. West Germany comes next with a 20.12 per cent share. The next biggest contributor is Belgium with 5 per cent; then comes Britain with 2.47 per cent, followed by Spain, the Netherlands, Italy, Switzerland, Sweden and Denmark.

Photo: Messerschmitt-Bölkow-Blohm

MILESTONES

November

19 NASA attributes failure of a hydrogen line on the nozzle of a Space Shuttle main engine to use of improper welding wire. The failure occurred on 4 November during an automatic shutdown of a three-engine cluster of test engines at the National Space Technology Laboratories. "Use of the improper welding wire severely decreased the strength of the weld on a segment of hydrogen line known as the 'Steerhorn', near the base of the engine nozzle. When the line ruptured an oxygen-rich combustion resulted, extensively damaging the test engine."

24 Meteosat 1 at 19.30 hrs switches itself into standby mode because of an apparent overload situation on board. Attempts to switch the geostationary meteorological satellite back to full operating mode in some cases were successful but only for a limited time, ESA reported on 3 December.

December

10 RCA Satcom 3 communications satellite, launched by Delta rocket from Kennedy Space Center on 6 December, is "lost" during firing of its apogee kick motor.

11 Contracts worth $M1.15 each are awarded by NASA to Boeing Aerospace Company and Lockheed Missiles and Space Company for design definition studies of a new Solar Electric Propulsion System "that would become an integral part of the NASA Space Transportation System." The Solar Electric Propulsion System (SEPS) is a candidate for use on a number of future U.S. planetary and Earth-orbital investigations. Its very efficient propellant usage, long continuous operating lifetime, and use of solar energy to provide electric power, make it especially suitable for rendezvous with comets and asteroids, delivery of probes to planets in the outer Solar System, close observation of the Sun and extended duration operations in Earth orbit.

15 First attempt to launch three-stage ESA Ariane L01 satellite launcher at Kourou, French Guiana, is terminated within one second after engine ignition when two pressure sensors give false readings.

16 Soviets launch Soyuz-T spacecraft from Tyuratam at 15.30 hrs (Moscow time) into orbit of 201 x 232 km inclined at 51.6 deg to the equator; period 88.6 min. *Tass* describes the craft, which on this flight is unmanned, as an improved type of Soyuz carrying new radio communication, orientation and movement control systems and a computing complex. The Soyuz-T is intended to carry out transport operations in order to ensure the functioning of the Soyuz-Salyut complex. The flight programme envisages comprehensive experimental testing of the new systems in various modes of flight and joint work with the Salyut orbital laboratory. (See also Cosmos 1001 and Cosmos 1074.)

17 Space Shuttle main propulsion system is successfully test fired for 9 minutes 10 seconds at NASA'S National Space Technology Laboratories, Bay St. Louis, Mississippi. This was the first time the whole system has been operated for the full duration. The main propulsion test article consisted of a cluster of three Shuttle main engines mounted in a simulated Orbiter aft section and drawing propellants from a flight-type External Tank. During the test the three engines were throttled back from 100 per cent rated power to 90 per cent, then to 80 per cent and finally, to 70 per cent. Engine gimballing and pogo pulsing checks were also successfully accomplished. To check two-engine performance, one engine was cut off early, as planned, and the remaining two were run at 70 per cent of rated power for the last 45 seconds. No problems were encountered.

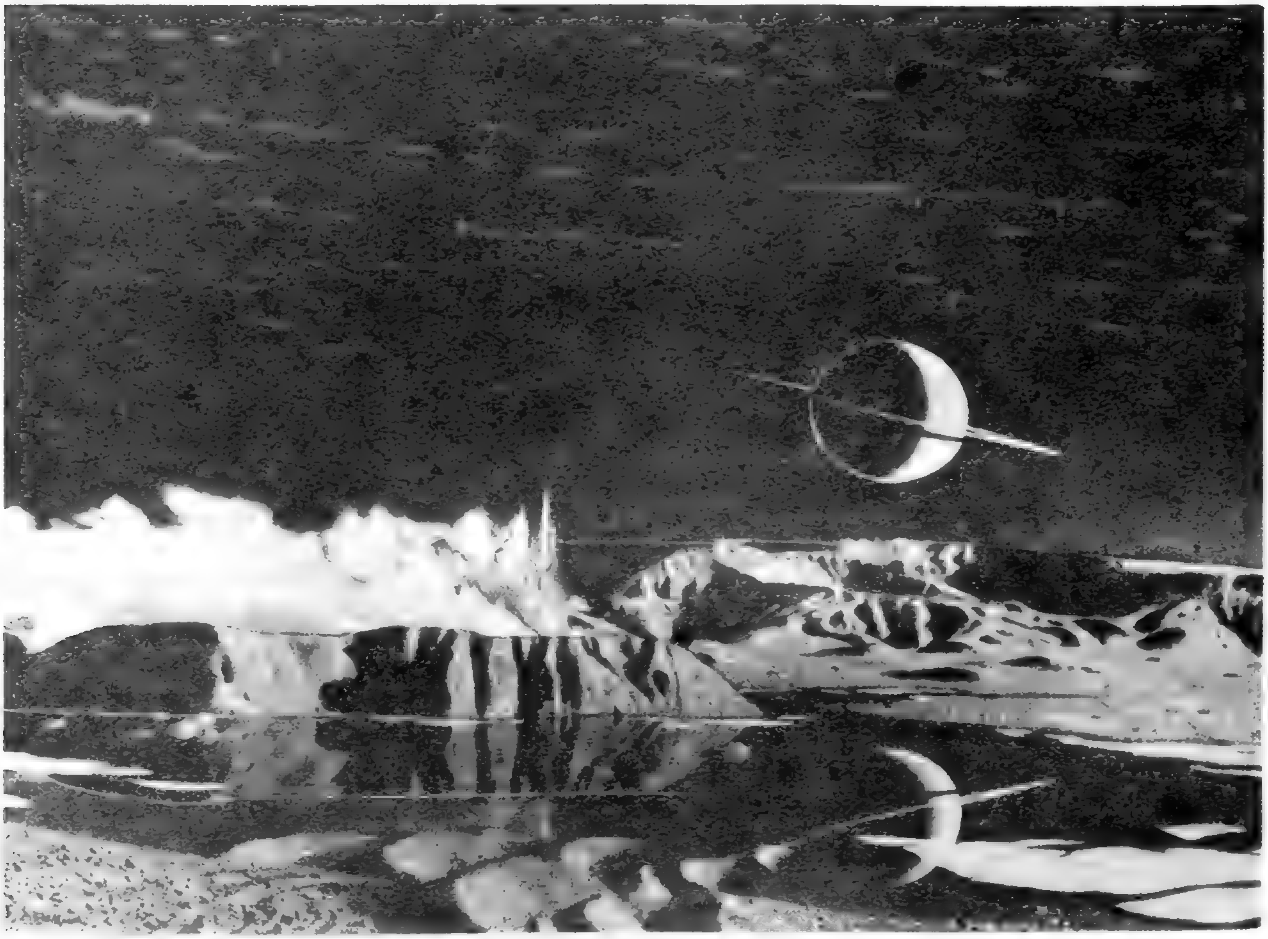
[Continued on page 141

В журнале не печатается ряд страниц.

SPACE: THE NEW RENAISSANCE

By Captain Robert F. Freitag

Remarks at the 10th Anniversary of the Apollo 11 Launching



MIRRORS OF TITAN. In this magnificent painting by artist Ron Miller, Saturn is seen from Titan, the ringed planet's largest moon. Titan dominates the satellite family in diameter and in mass and it exerts a measurable gravitational force on other bodies in the system. In 1944 the American astronomer, Gerard P. Kuiper, discovered that Titan possessed an atmosphere. It is composed mainly of hydrogen and methane with reddish clouds and may have methane lakes which gradually evaporate into the atmosphere.

National Aeronautics and Space Administration

On 16 July 1979 one of America's most distinguished "primemovers" of Astronautics, Capt. Robert F. Freitag, received the BIS Bronze Medal at a special meeting of the Society at the American Embassy, London. In his address following the presentation Capt. Freitag took as his theme the exciting new opportunities for mankind that are opening in the aftermath of the Apollo epic.

Mr. President, Mr. Ambassador and guests:

It is with deep appreciation that I accept the special honour your Society has chosen to bestow upon me today. I feel that this recognition goes far beyond an individual's effort and is, in fact, another recognition of the great space team that made today an anniversary of a most special day in the history of mankind.

Ten years ago today three valiant astronauts were launched on their epoch mission to the Moon seeking to fulfill one of man's oldest dreams, - to journey to another heavenly body outside this world.

The choice of this venue, - London, to take note of this historical anniversary and the initiative of the British Interplanetary Society in fostering this special observance is particularly significant in my opinion.

Presented at a Special Meeting of the British Interplanetary Society, American Embassy, London, England 16 July 1979.

The British Interplanetary Society is a most unique organization. In its 50 years of pioneering effort in promoting the world's space effort it has constantly been in the forefront of imaginative and bold thinking - with a remarkable degree of success and accuracy.

I recall, for example, a special meeting of the Society nearly eleven years ago at which the first identification of the Space Shuttle took place. Though the concept of reusable space transportation had been espoused by BIS authors and others over the past several decades, it was August 1968 that the first precise description of the Space Shuttle, its concept of operation and its plan of development was set forth. As with their very much earlier predictions of lunar flight, planetary probes and applications satellites, today we still see the Society in the forefront of the thinking and planning associated with exploration of the Cosmos. Your Society is to be congratulated on a long record of progress to which I offer a hearty, "Well Done!"

It is always a delight to return to London. From my earliest visits at the end of World War II while assigned at the U.S. Naval Attache's Office here at Grosvenor Square through the many involvements in joint US-UK endeavours in aircraft, guided missile and space systems over the past three and a half decades, I have always found working with the British technical community to be most stimulating and rewarding. I see friends in the audience who have shared these experiences - from the World War II guided missile examinations at the Bramshot Golf Course; to long days and nights in the cold halls off Bryanston Square where early planning of ballistic rockets took place. Or, after the first exciting days of Sputnik seeing perhaps the world's earliest full scale mock-up of a space station erected in Olympia Hall in 1960 sponsored by the London *Daily Mail*. Or, more recently in the early '70s, the intimate planning trying to bring about European-American cooperation in space research in the post-Apollo era which resulted in the development of the European Space Agency's SPACELAB in which Britain plays a prominent part. And now, as we approach the 1980s, new efforts looking toward extending our traditional cooperation are being explored in the fields of space sources for generation of energy and other applications for the benefit of mankind.

To return to the anniversary of the launch of Apollo 11. I am certain that each of those present today can vividly recall where they were and what their thoughts were at the time the Spaceship Eagle touched-down on the Moon and as Neil Armstrong took that "One small step." Certainly, for those who participated in that great endeavour their lives will never be the same again. What can one do for an encore? As the noted British author Arthur C. Clarke* commented at the time, "It was a perfect last day of the old world."

It is sometimes difficult to accept the state of progress of modern technology. Just ten years ago today I was standing at Cape Canaveral watching tens of thousands of well-wishers of the space programme applauding not only "a good shoot" but man's venture into his Universe. Standing there, listening to those average Americans and world-wide guests clapping so bizarre an event, it was hard to realize that a mere generation before only a few hardy science fiction readers could even imagine what turned out to be the sight of the century.

Beginning with Apollo 11, twelve astronauts left their footprints in the lunar dust between 1969 and 1972. They totalled

Past-Chairman, British Interplanetary Society.

Capt. Robert F. Freitag.

SOME CAREER HIGHLIGHTS

A full account of Captain Freitag's many contributions to Rocketry and Astronautics will be found in *Spaceflight*, December 1979. Currently, he holds the position of Deputy Director, Advanced Programs, Office of Space Transportation Systems NASA. We invited him to give some further details of his multi-faceted career:

1963 – *Director of Launch Vehicles and Propulsion, NASA Headquarters*. This job involved the overall direction of the development of the Saturn I, IB and V launch vehicles, the associated engines, the launch facilities at KSC, the production facilities at the contractors' plants and the associated support facilities at the NASA Centers. Coordination of the Titan II launch vehicle for Gemini, being developed by the USAF, was included.

1964-70 – *Director of Field Center Development, NASA Headquarters*. In late 1963, NASA underwent a major reorganisation when Dr. George Mueller came aboard and the launch vehicle development was fully delegated to the Centers. The Headquarters function became an *overall* Apollo programme effort. In this capacity, I held several responsibilities; one being the overall management of the Manned Space Flight Field Centers (Kennedy, Marshall, and Johnson) and, two, the handling of all Congessional Affairs for the Apollo and Gemini programmes. This latter job emerged as a most important, and quite personal, task of keeping the programme "sold" and working out such critical problems as the Apollo 204 Fire hearings which were vital to the programme. There were also many "adventures in this era too numerous to mention in a short biography. One I recall of special interest to your members would be the fact that our team wrote the significant speech for George Mueller, "Manned Space Flight: The Future," where the plans for the Shuttle were first enunciated to the world at a BIS meeting in London on 10 August 1968.

1970 – *Mississippi Test Facility, Bay St. Louis, Mississippi*. Another example of the wide-ranging tasks of my "Field Center Development" years was an interesting diversion in 1970. In August 1969, the most devastating hurricane ever to strike the United States came ashore at Bay St. Louis, Mississippi, the location of the NASA Mississippi Test Center. Thousands of millions of dollars of damage and hundreds of lives were lost. The idea emerged that if NASA were placed in charge of the recovery effort and the management of the dozen or so groups furnishing recovery aid, that the two thousand million dollars of aid could be "system engineered" so that the whole might be much greater than the sum of the parts. I was sent to Mississippi for most of 1970 to head this relief effort and did succeed in providing integrated management for rebuilding the Gulf Coast.

1970-73 *Post Apollo Planning* – From late 1970 through the SPACELAB go-ahead date in 1973, I served as Special Assistant to the Associate Administrator for MSF for the purpose of evolving a programme for US/European cooperation in the Post-Apollo era. This involved a continuing relationship with ELDO and ESRO, the various Space Officials of the involved governments, numerous European laboratories, and a wide spectrum of European contractors. The procedure involved an early education process on US Post-Apollo planning; the solicitation of cooperation proposals from government and industry; the establishment of working relationships across the Atlantic; the evaluation of proposals and options; and the selling of the project which eventually became SPACELAB.

1973-todate *Advanced Programs Office*, NASA Headquarters, Washington, D.C.

166 man hours of surface exploration, traversed almost 60 miles and brought 850 pounds of lunar rock and soil samples back to Earth. They left 60 major scientific experiments on the Moon and conducted 34 more in lunar orbit. Approximately 33,000 lunar photographs and 20,000 reels of magnetic tapes of geophysical data have been collected, causing a major revolution in planetary science by providing the first deep understanding of a planet other than Earth. And, in some ways even more remarkable, all this was being done openly while the world watched on live television!

What Did We Learn?

But what has conquering lunar space yielded for the benefit of mankind? What did we learn? What does it all mean?

Historians have written much in this past decade and the analyses will continue throughout our and our children's lifetimes and in the centuries beyond. As Wernher von Braun noted shortly before his death:

> *When people in the 22nd Century and beyond look back to the 20th Century, this Century will stand out clearly as the time when man first left this planet and travelled in space. Memory of almost everything else that we experience will be eclipsed by the passage of time.*

Certainly Apollo was more than the great technological achievement of building a giant rocket and spacecraft – over eight million individual parts all working together perfectly under most difficult conditions. Certainly it is much more than mounting the largest single technological enterprise and directing the efforts of over a half million people towards fulfillment of a single mission on time – within cost – and with perfect performance. Yet as we increasingly undertake massive global enterprises of this scope and larger, the boldness and management techniques will look back to Apollo as the model.

But far more significant will be the lasting effect on the soaring spirit of man. Whether near term or far term – the world will never be the same.

I recall the last issue of *LIFE* magazine published in the 1960s. An editorial summing up the decade of the '60s deplored the decay of life in the USA in that decade: – the assassinations of John and Robert Kennedy and of Martin Luther King; – the rash of strikes, riots and demonstrations; – the rise of the drug culture and decay of human institutions; – the popular reaction against Viet Nam actions. Yet, noted *LIFE*, the decade ended with one of mankind's greatest achievements – the landing on the Moon. Such a demonstration of resolve, intellect and leadership must be the true representation of man's spirit.

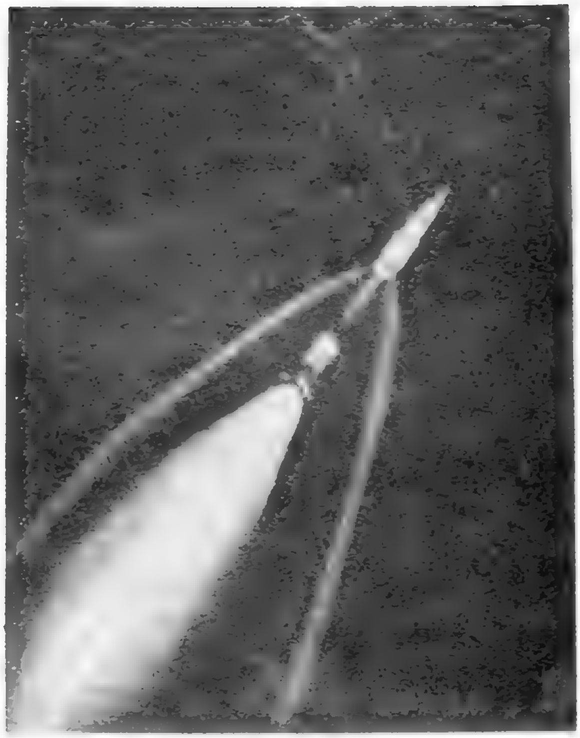
However, there is much temptation to look for the nearer term, more practical benefits of space. Space flight represents a massive investment in material resources, critical manpower and financial investment. What is the practical return on this investment?

Already, the world is seeing many operational space systems for communications, – with over 75 satellites operating routinely for intercontinental and domestic communications, yielding vastly improved transfer of information at a fraction of the cost of their predecessor systems.

Today, navigation satellites are routinely providing ship locations and other data to over 2,000 ships on the seas – at all points on the globe – in all weather – for all nations of a heretofore unachieved accuracy.

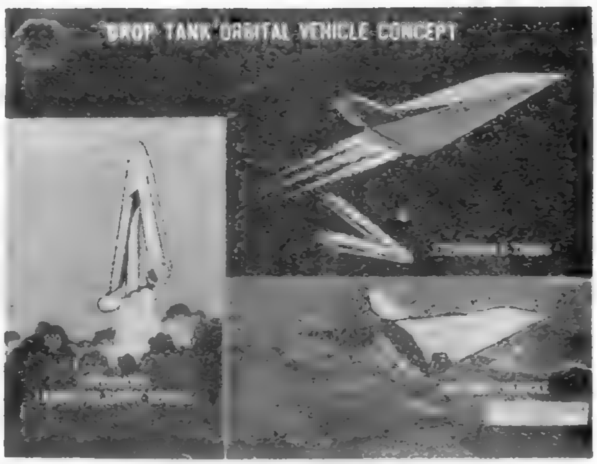
Observation satellites are providing global weather data, crop assessment information, geodetic data for mapping and survey, and for invaluable defense purposes.

The decade of the '80s can see these systems extended to provide permanent, eventually self-financing, services for worldwide communication, weather and ocean forecasting, Earth resources discovery and monitoring, determination of



FIRST MEN ON THE MOON depart Planet Earth on 16 July 1969. Photograph taken 2½ minutes after lift-off at 9.32 a.m. EDT shows separation of S-IC booster of Saturn V at an altitude of about 61 km, some 88.5 km downrange from Launch Complex 39A at Kennedy Space Center, Florida.

NASA



Concept of the Space Shuttle described to the British Interplanetary Society on 10 August 1968 (see page 99). The combined lifting-body spacecraft and rocket booster employed "wrap-round" expendable tanks. Overall length of space vehicle (drop tanks omitted) 82 ft (25 m); span over stabilisers 52 ft (15.8 m); height, undercarriage extended, ground to tip of stabiliser, 24 ft (7.3 m). Object: to ferry 25,000 to 50,000 lb (11,340 to 22,680 kg) payloads into near Earth orbit.

NASA

SPACE SHUTTLE Orbiter "Enterprise" is etched against a dry lake bed during an approach-and-landing test at Edwards Air Force Base, California. In 1977, the "Enterprise" astronaut crews made five successive free flights from a 747 carrier aircraft, verifying the Orbiter's subsonic airworthiness and the landing techniques required after returning from space missions.

NASA

SHUTTLENAUTS. The two men who will make the first test flight of a Space Shuttle into orbit - aboard the Orbiter "Columbia" - later this year: *Left*, Astronaut John W. Young, commander, and Astronaut Robert L. Crippen, pilot.

NASA

compliance with international arms agreements and the prediction of natural events of disastrous human consequences or broad scale economic impact.

From space, nearly all of today's functions are based upon a few simple concepts. A spacecraft orbiting the Earth serves either as a very high antenna for transmitting or receiving information; or as an observation platform for looking at Earth, at astronomical bodies or at other objects in space; or as a reference point or measurement benchmark or, in effect, an "artificial star." Of increasing importance is a fourth function of a base for doing things *in* space.

It is this latter aspect that offers great opportunities for growth and expansion in space and significant benefits only vaguely perceived at this time.

Challenge and Opportunity

Space has at least six characteristics not found here on Earth. First, there is the great view, what we call the overview factor. The operational systems just mentioned depend on this characteristic. Second, there is an almost perfect natural vacuum which can be a boon to a great many manufacturing processes. Third, in Earth orbit there is almost total absence of gravity. You can build huge structures with the flimsiest of materials. Fourth, there is almost an unlimited supply of energy from the Sun. Fifth, space constitutes a vast disposal area for the rejection of heat or radiation and other by-products of manufacturing. Sixth, you can achieve what amounts to perpetual motion in space – a billion miles per gallon, so to speak.

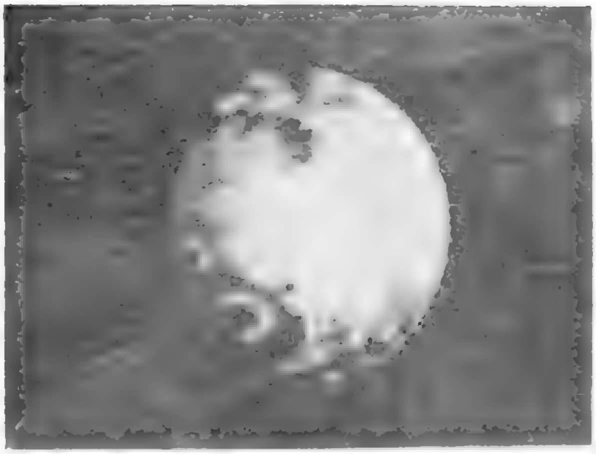
To capitalize on this environment, the world must improve upon the very expensive technique of using throw-away or expendable launch vehicles as has been the case in the first two decades of the Space Age. It has been the major goal of the USA in the decade of the 70s to achieve easy, – and economical access into and out of space. The reusable Space Shuttle, nearing the completion of development, will achieve this goal. The Shuttle will permit routine operations in near space including the placement of 'conventional" satellites as we know them today and will, more importantly, allow the establishment of permanent bases in orbit for the conduct of routine manned operations in space.

By making entirely new working conditions accessible to man that cannot be duplicated on Earth in their entirety, the Shuttle and associated space stations will establish a departure situation for beneficial innovation, new industries and new operations not concretely predictable at this time.

As the '80s unfold, the Shuttle with its European-developed SPACELAB will commence the first experiments to bring about this coming era of Space Industrialization. The construction of large structures, perhaps a 100 metres or more in diameter, fabricated by "hard-hats" in orbit, will open new possibilities for communications. Perhaps an early application will be a wrist-watch telephone system, global in scope, operating with its giant "switchboard in the sky." Or the processing of materials in the weightlessness environment of space that would permit entirely new properties and characteristics. Among the most promising avenues of exploration is, again, an orbiting system based upon fabricating very large solar collectors on orbit, perhaps several kilometres in size, to generate electrical power and beam this energy to receivers on Earth for distribution wherever needed. The possibility of space technology providing a source of inexhaustible, clean energy cannot be ignored.

These opportunities, together with continued scientific explorations and even more advanced space transportation will open the Cosmos in no less a fashion than did the explorations of the 15th and 16th centuries.

The decade of the 1970s has truly been an exciting time for a space buff to be alive. Mankind has visited four planets of the Solar System with robot explorers – Jupiter, Venus, Mars and Mercury and, in about six weeks, will venture to a fifth planet – Saturn, when the Pioneer 11 will encounter and explore this distant companion of Earth. Only last week, Voyager 2 passed Jupiter and added to the startling discoveries about Jupiter which began earlier in the year with Voyager 1. And as a related thought the same type of vehicles and space systems used for planetary exploration, launched from the Space Shuttle, might provide a means for transporting and storing our nuclear waste in deep space.



COSMIC VOLCANO. This picture of the Jovian moon Io was taken by Voyager 2 on 4 July 1979 from a distance of 2.9 million miles (4.7 million km). The first volcano discovered by Voyager 1 is again visible in the lower left portion of the disc as a dark oval with a dark spot in the centre.

NASA

For the first time in our history we have the means and the tools to consider the Earth as a global whole. Whether it be orbiting antennae for massive global communications, or a platform for Earth observations on a continental scale or a space-based observatory for study of the Sun, the planets and the stars – all have yielded new understanding of our "Spaceship Earth" and opened the door for new, unimagined futures.

Our challenge now is to remain resolute in our explorations. We must be willing to try the new and to invest in the future. It is not easy. The challenge is somewhat akin to what the Red Queen told Alice in *Through the Looking Glass,* " . . . it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run twice as fast as that!"

This challenge is accompanied by opportunity. Recently, before the United States Senate, James Michener commented on these conditions:

> *There are great tides which operate in the history of civilization and nations must remain alert to the force of these tides and how they may be utilized. The great voyages of the Renaissance with the spiritual awakening of the times is the classic example. But I believe that there are moments in history when challenges occur of such a compelling nature that to miss them is to miss the whole meaning of an epoch. Space is such a challenge. It is just this challenge that Shakespeare sensed nearly four hundred years ago when he wrote:*
>
> *There is a tide in the affairs of men Which, taken at the flood, leads on to fortune; Omitted, all the voyage of their life Is bound in shallows and in miseries. On such a full sea we are now afloat, And we must take the current when it serves, Or lose our ventures.*

I believe that today we are witnessing the genesis of such a tide. I believe the great explorations of space are offering mankind a new opportunity – a new environment – and a new set of tools to allow us to shape our destiny.

EXPLORING THE VEILED PLANET

Staff of NASA

More findings of Pioneers Venus 1 and 2

Canyon on Venus
Venus's huge valley, the largest yet found in the Solar System, is much deeper than similar formations on Earth, where most valleys have been formed by erosion rather than by fault activity. It also appears to be larger than *Valles Marineris* on Mars. The features on Mars and Venus may indicate that the two planets have undergone much different activity than that experienced on our own planet.

The canyon's shape suggests to scientists that internal planetary forces have broken open Venus's crust to create the formation, because erosion or the impact of a meteorite would not be likely to cause such a long, linear feature. Also, Venus's canyon is interrupted every 30 to 60 miles (48 to 96 km) by offsets which appear to be similar to the transverse faults in most rift valleys on Earth. Such formations here include the Rift Valley of East Africa and the Mid-Ocean Ridge. Scientists were unable to tell when the Venus fault activity occurred or whether the internal forces are still at work.

Radar Imaging
The Radar Mapper of the Pioneer Orbiter, which had malfunctioned during the second month of orbit, has since completely recovered both its altimetry and imaging capabilities. It had worked normally for the first 10 days of orbit in December 1978, but by mid-December the data had become degraded.

When examined in early January, the instrument was recycling at 49 pulses instead of completing the required 64. Believing the cause to be either a temperature or charge build-up, controllers turned off the instrument. On 20 January 1979 it was again turned on and had improved considerably. Experimenters then had the instrument turned on once daily during its two-hour operation period. By 29 January the altimetry mode had fully recovered, and on 14 February the imaging began to perform normally.

Altimetry data provide heights of terrain on Venus, mapping a belt around the planet which spans 130° of latitude. Recording areas of the planet not visible from Earth-based instruments, the radar covered latitudes from 75° north to 63° south, revealing surface characteristics of geographical features.

Continuous Lightning Confirmed
The Soviet Venera spacecraft, which entered Venus's atmosphere in late December, detected 13 minutes of electromagnetic signals similar to terrestrial lightning storms. The signals began at about 19.8 miles (32 km) and ended at about 1.2 miles (2 km). At times, the Soviet spacecraft detected as many as 25 strokes of lightning per second, an essentially constant bombardment of Venus's atmosphere.

Thirty-two minutes after landing, Venera 11 acoustic equipment detected a very loud (82 db) noise which is believed to have been thunder.

The first US detection of lightning came on 30 December 1978, when the Pioneer Venus Orbiter instruments picked up intense and highly impulsive electric field signals characteristic of terrestrial lightning. Detected during the first day that the Orbiter's point of closest approach occurred on the night side of Venus, the signals were picked up near that closest point.

Scientists said the lightning signals, which are well below the ionopause, are detectable either because they are coming through "holes" in the ionosphere, or because they are "whistler" signals which are able to pass through the ionosphere. Whistler radio waves on Earth are generated by lightning or by high-energy electrons.

The Polar Hole
Major findings also have come from infrared observations. The 683 miles (1100 km) wide clear area in Venus's clouds is located near the centre of the north polar vortex. Dr. Fredrick Taylor of Jet Propulsion Laboratory attributes this relatively small "polar hole" to strong downflow in the atmosphere. This would drive the polar clouds down to lower, hotter levels where they would evaporate and may disappear entirely.

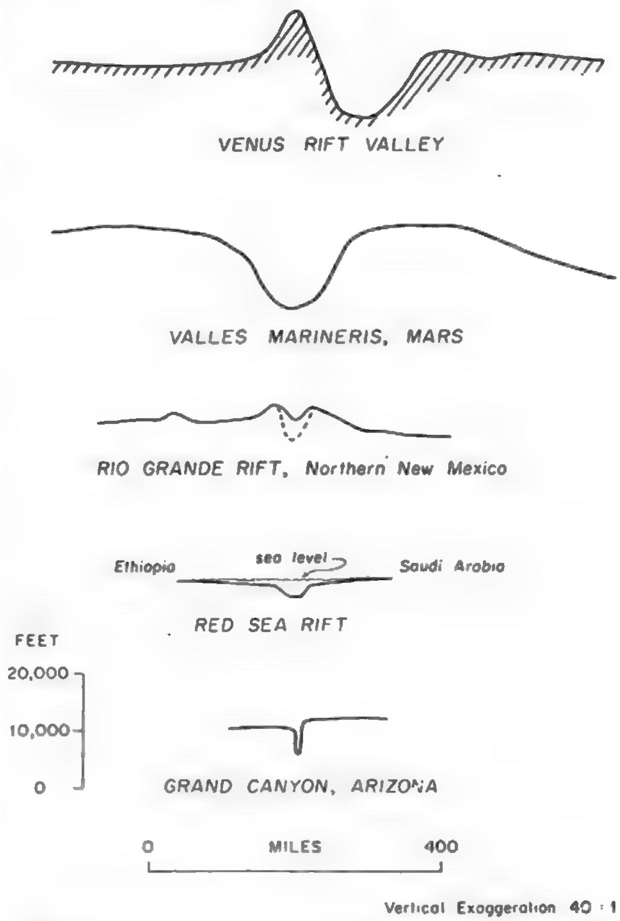
The Pioneer Venus data on the planet's winds is not yet available. However, if the apparent down-flow of wind at the poles is real – and is powerful enough to sweep away most of the clouds – it may provide a key piece in the puzzle of the global circulation of the planet's atmosphere.

The Pioneer Sounder Probe at Venus's equator and the North Probe near the pole, combined with the infrared instrument, have made related significant findings.

In the atmosphere above the clouds from 43.5 – 56 miles (70-90 km) altitude, Venus's stratosphere – temperatures increase going from equator to poles. Solar heat comes in to Venus mainly at low latitudes, so the unheated polar regions should be cooler. If instead the poles are hotter, an equator-to-pole circulation and downward polar flow is hard to explain.

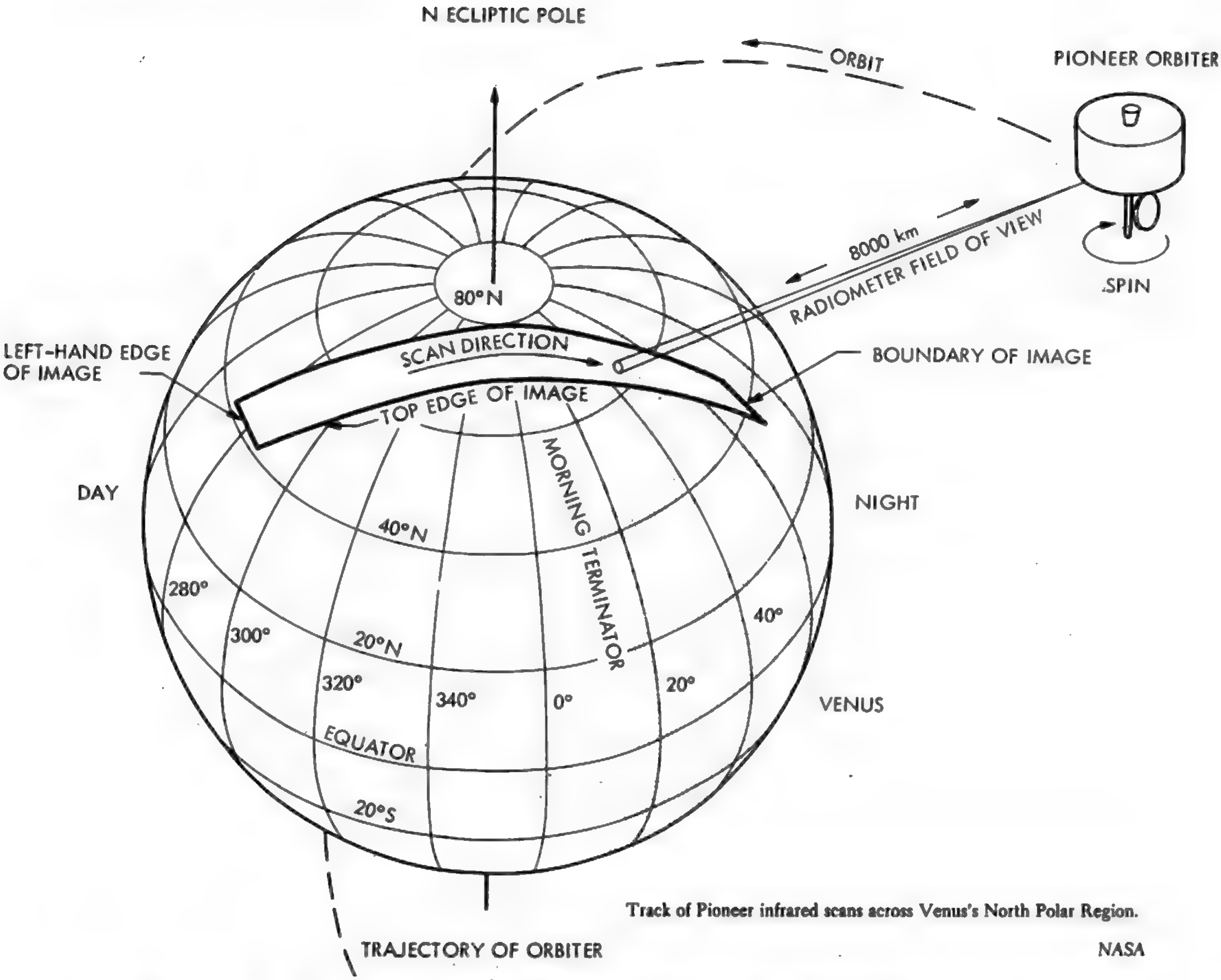
However, the two Pioneer probes found that below the clouds, at around the 37 miles (60 km) level, this trend reverses, and the polar regions are indeed cooler.

The attempt to put the North Probe into the circumpolar cloud region was successful. The North Probe found that at 37.2 miles (60 km) altitude, polar temperature was 30°C lower than temperature measured at the equator at the 60 km altitude level by the Sounder Probe.



VENUS RIFT VALLEY compared with crustal faults on Earth and Mars.

National Aeronautics and Space Administration



Track of Pioneer infrared scans across Venus's North Polar Region.

NASA

According to Alvin Seiff of Ames Research Center this reversal in equator-to-pole temperature patterns a 60 km altitude suggests two circulation cells: An equator-to-pole cell in the lower atmosphere and a pole-to-equator cell in Venus's stratosphere (above 60 km) driven by the massive equator-to-pole circulation cell lying below it. The down-flow at the pole is part of the lower cell, driven by the 30° C temperature difference between the equator and 60° north latitude. The upper circulation cell can explain why the polar stratosphere is warmer than that near the equator.

The cloud top temperatures increase from the equator to mid-latitudes, then cool down by as much as 40°C at about 70°N latitude (20° from the pole). The temperatures increase again over the poles to their mid-latitude values.

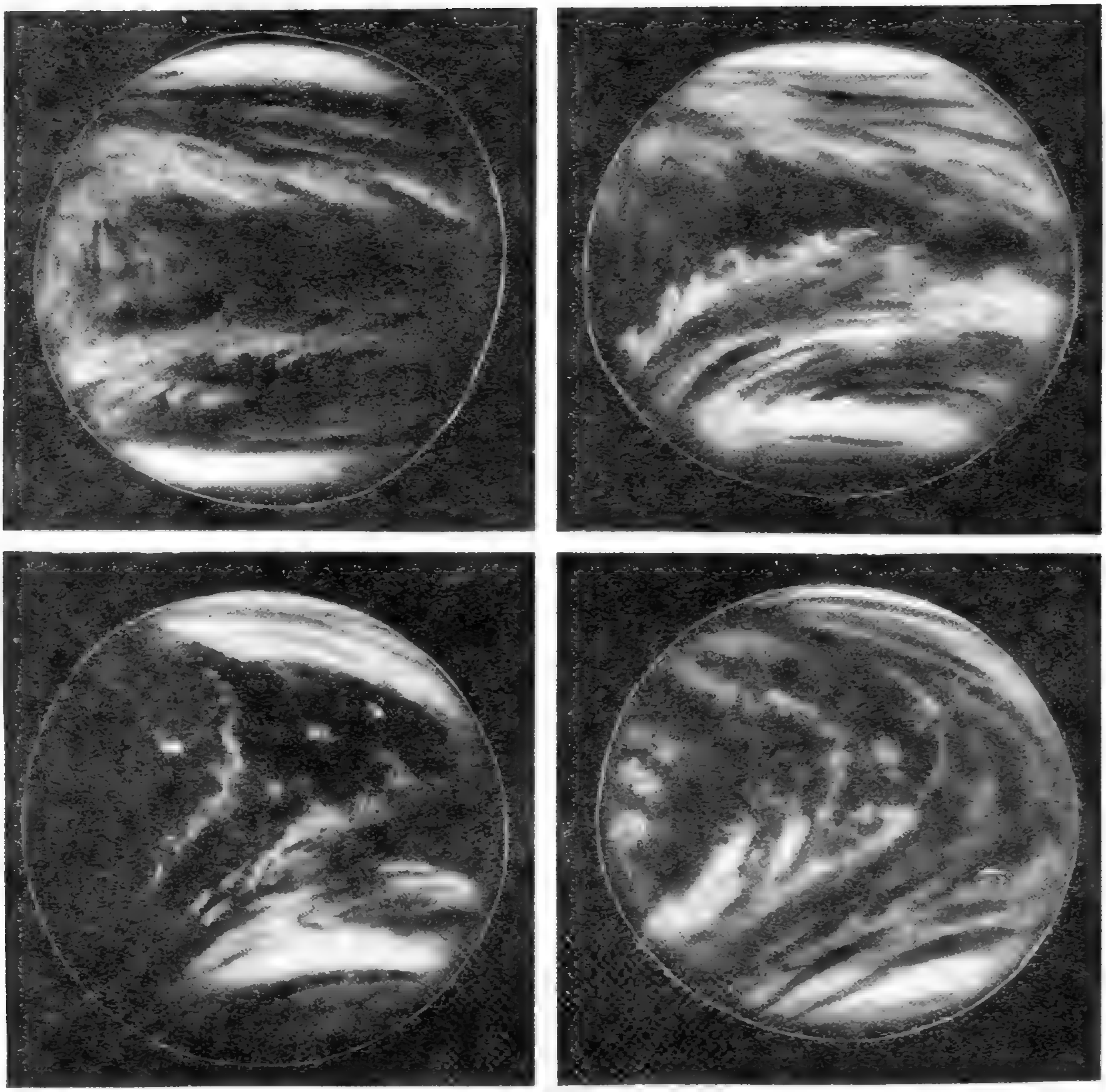
The cool region at 70° north latitude is a ring of cold, high clouds around the pole. North of this ring, there is a polar depression in the clouds about 9.3 miles (15 km) deep. This depression is about 1,860 miles (3000 km) in diameter, three times wider than the planet's relatively cloud-free polar hole.

Global Atmosphere Findings

Temperature and pressure profiles from all four probes (two on the day side and two on the night side) now show that conditions in Venus's atmosphere beneath the clouds are startingly uniform. Over the entire cross section of Venus's atmosphere from the cloud tops, down to the surface, a vertical distance of 30 miles (48 km) these profiles coincide almost exactly. This means that atmospheric temperature and pressure in most of the atmosphere (99 per cent of it) are almost identical everywhere on Venus – at the equator, at high latitudes, and in both the planet's day and night hemispheres. This, in turn, means the Venus weather machine is very efficient in distributing heat evenly.

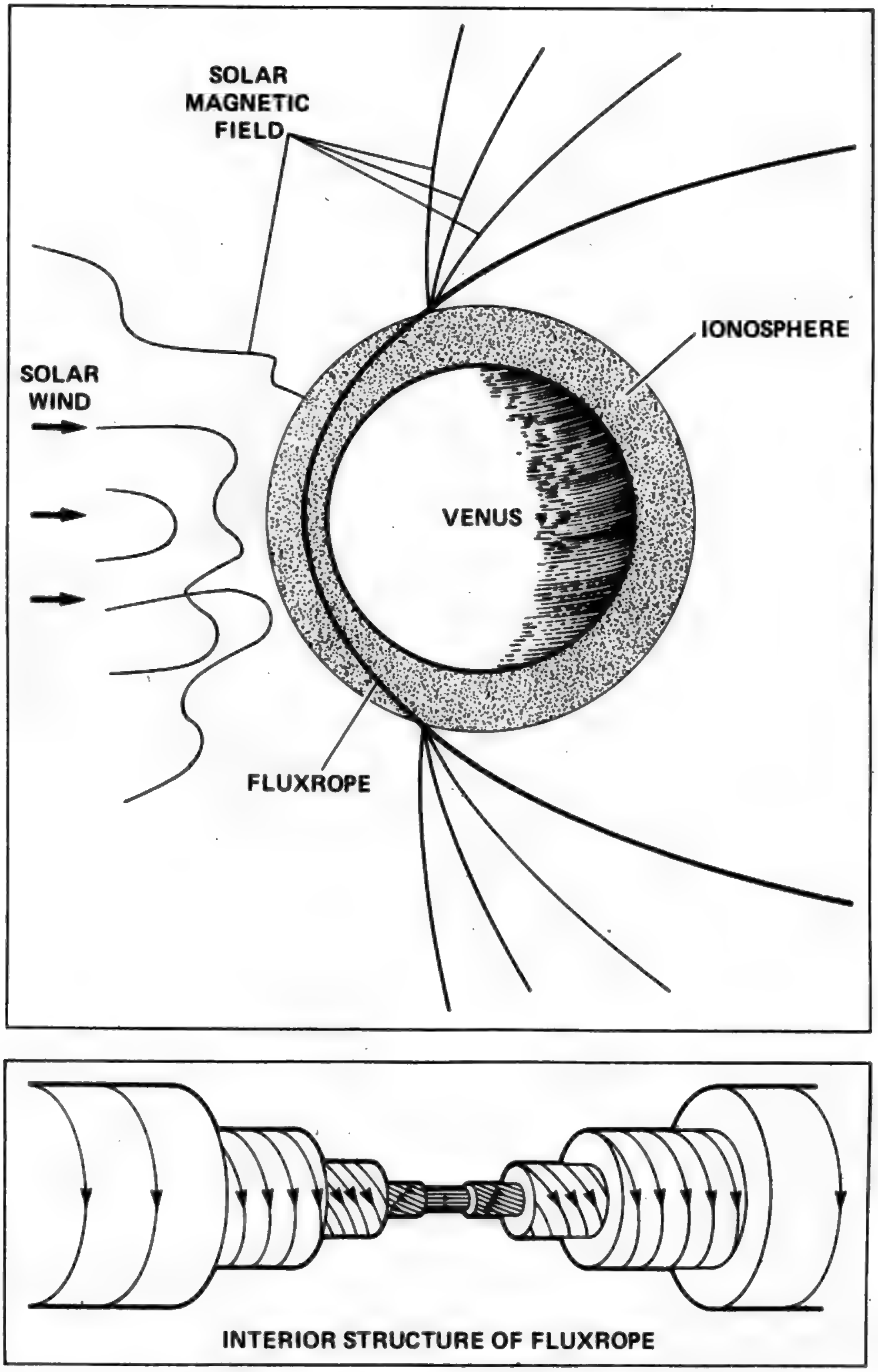
The Venus probes also found somewhat milder than expected conditions at the surface. Temperature at 457°C (854°F) instead of 492°C (917°F) was 63°F lower than expected. Pressure at the surface also was lower than expected – about six Earth atmospheres lower, 90.5 instead of 96.5 atmospheres.

It now appears that the characteristic planet-spanning C- and Y-shaped dark markings in pictures of Venus taken in ultra-violet light are due either to global breaks in the bright, highly reflective upper cloud deck or to massive upwellings of sulphur compounds to altitudes where they can be seen through the thin upper clouds. Dr. Ian Stewart, University of Colorado, reports that his ultraviolet spectrometer apparently has seen a new aspect of these lower, dark, cloud features. He has identified sulphur dioxide clouds which seem to coincide closely with Venus's global patterns of C- and Y-shaped dark markings.



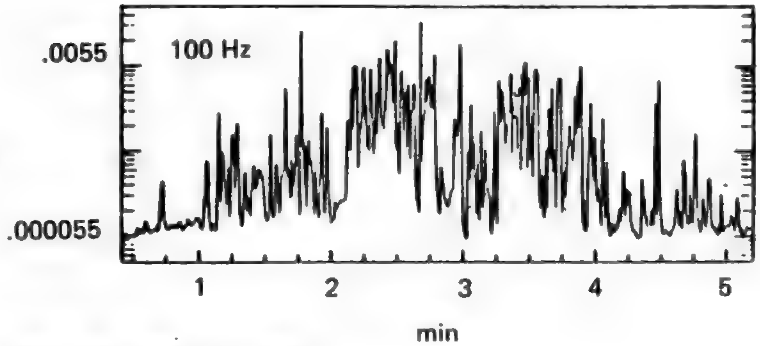
These four images of Venus were taken from February to 3 March 1979. The first image shows a relatively dark, uniform band in the equatorial region. Superimposed on this are numerous, small scale cellular features. The bright, polar bands in each hemisphere have their equatorward edges aligned nearly parallel to latitude circles. The second image shows a dark, almost triangular shape in the middle and western portion (left) which is the tail of the dark "Y". The bright polar band in the southern hemisphere is very irregular with a branch on the left hand extremity, making a substantial angle with parallels of latitude. The remainder of the band is disrupted by a series of dark tilted streaks. The third image shows a small wedge-shaped dark feature near the left hand side which might have been a "Y" feature that was not well developed. The south polar band feature exhibits a series of sharp boundaries produced by dark tilted streaks. The dominant feature of the fourth image is a family of bow shapes extending from the west (left) to the centre of the disc. This type of feature may well be the reversed "C", noted by ground-based astronomers. Again, through the entire central portion of the disc, dark and bright walled features are noted.

NASA



Principle of "magnetic ropes", magnetic field structures detected in Venus's ionosphere (see facing page).

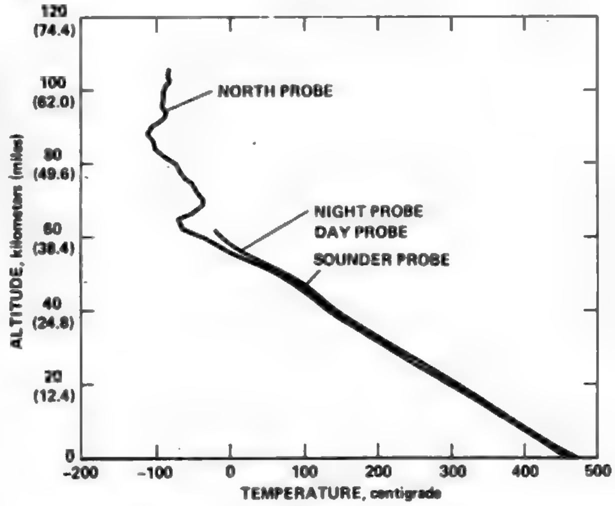
NASA



Lightning measurements on Venus, electric field detector, Pioneer Orbiter, 21 January 1979.

NASA

Below, graph shows that Venus's temperatures coincide globally.



The dark markings in the Venus ultraviolet pictures are still believed due to absorption by elemental sulphur. However, the Pioneer atmosphere measurements suggest that sulphur dioxide and sulphur should be found together in the clouds, as part of the atmospheric sulphur cycle (which may be something like Earth's water cycle). Therefore, the huge sulphur dioxide clouds reinforce the idea of a regular pattern of planet-spanning breaks (or upwelling features) in Venus's upper cloud layer. The presence of sulphur dioxide in these patterns also suggests flow or regular wave motions in the planet's atmosphere.

Venus's Sulphur Cycle

Although much more work is needed, scientists now believe the basic sulphur cycle in Venus's clouds goes something like this:

Sulphuric acid droplets together with liquid and solid sulphur drift down through the clouds heating up as they go. At the bottom of the densest cloud layer (48 km), the material begins to vaporise and split up.

The breakdown products, water, sulphur dioxide, oxygen, and various sulphur compounds, then recirculate up through the clouds, where they are reformed into sulphuric acids and sulphur through reactions that probably involve solar ultraviolet radiation. The absence of free oxygen and water vapour in the upper atmosphere indicates that these two compounds are being removed by vigorous reactions within the clouds.

New Planet Pictures

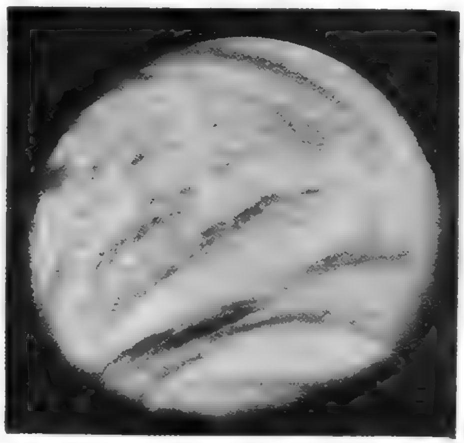
Pioneer Venus Orbiter now has taken hundred of pictures of the cloud patterns. They show that Venus's dark markings are below the reflective upper cloud layer and that the clouds near the poles currently are much thicker, and hence 10 times brighter than they were during the Mariner 10 flyby in 1974. Pictures also show that one of the planet's characteristic Y-shaped features has moved through the sub-solar (Sun-facing) point on Venus's cloud tops in recent weeks. Previously, it had been thought the "Y" features may be directly related to the sub-solar point.

There also appear to be many more circular cells than previously observed and some new types of cells. These may be convective cells something like Earth's thunderstorms.

Magnetic "Ropes"

Unique magnetic field structures have been detected for the first time in Venus's ionosphere by the Orbiter Magnetometer instrument. Twisted magnetic field lines, wrapped around each other like woundup ropes, appeared as spikes in the Magnetometer readings, sometimes as intense as the built-up solar wind magnetic field outside the ionosphere. Because Venus does not have a magnetic field, the solar wind constantly bombards the top of Venus's ionosphere. When the solar wind encounters the obstacle of this ionosphere, most of it flows around the planet, but the solar wind magnetic field tends to build up at the boundary. Scientists suggest that the solar wind magnetic field may be diffusing through the ionosphere in these twisted, rope-like field lines.

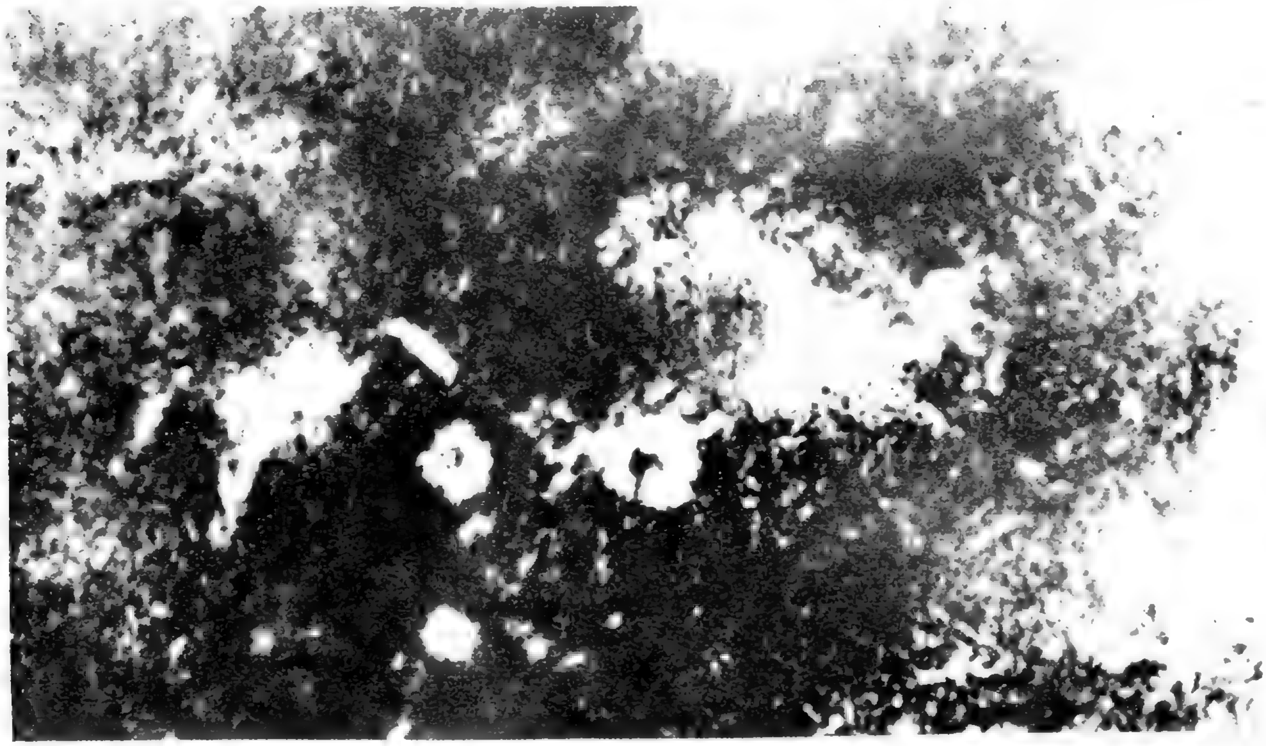
Another theory is that the magnetic-field spikes are induced in the ionosphere by electric current flows in the solar wind.



NASA

This full-disc image of Venus was taken by Pioneer Venus Orbiter from a distance of 59,000 km on 14 February 1979. The image looks unusual because the terminator is at the bottom of the picture.

RADAR IMAGES OF VENUS. Scientists working for NASA and the National Science Foundation made these radar images of Venus with the 12 cm wavelength radar of the Arecibo Observatory, Puerto Rico. This image covers part of the area between latitudes 9 and 31° north (1,500 miles, or 2,400 km) and between 269 and 311° longitude (2,800 miles, or 4,500 km) at an average resolution of 7 miles (11 km). The large bright feature to the left was one of the first discovered on the planet in the 1960s and was provisionally named "Beta" at that time. It is still not clear whether it is of volcanic origin. Results from the Goldstone radar at JPL give it a height of approximately 6 miles (10 km) which would indicate it is of volcanic origin. Just to the right of centre is a crater surrounded by an irregular bright area which may also be evidence of volcanism.



This radar image shows a cratered area just to the west of the large feature "Alpha". The area covered is between 31 and 19° south latitude (800 miles, or 1,300 km) and from 329 to 351° longitude (1,400 miles, or 2,300 km). The resolution is about 4 miles (6 km). The large central dark area is a region of generally low radar echo strength, indicating that it is probably relatively smooth except in the vicinity of the craters themselves. Except for bright central features, the interiors of these craters - which are between 20 and 40 miles (30 and 60 km) in diameter - are also relatively smooth. They are probably the result of impacts on the surface, but a volcanic origin cannot be ruled out.

NASA

SALYUT 6 MISSION REPORT: PART 2

By Neville Kidger

The Lonely Vigil in Orbit
Continued from February issue

PROGRESS 6

Real-time Planning

Following the failure of the Soyuz 33 flight Soviet mission planners were forced to sit down and face a problem that they had not expected. The severity of the Soyuz 33 failure meant that perhaps the Soyuz 32 engine system could experience a similar fault; measures were forced upon the Soviet planners with which they were unaccustomed – real time planning, in US terminology.

On earlier Soyuz flights, in the event of failure of one system or another, the flight was abandoned and the mission goals reassigned to the reserve crew on the next flight. This conservatism is evidenced by the fact that it took the Soviet Union four years to achieve a basic two-flight, increased duration stay, Salyut mission, from the initial troubles of Salyut 1/Soyuz 10 and 11 through the Cosmos 557 Salyut failure to the eventual success of Salyut 4. With Salyut 6 the circumstances were different. With two men actually in space – with a possibly defective spaceship – the Soviet Union at last showed the increasing maturity of its Salyut programme. On this series of flights there was to be no turning back; the problems would have to be solved as the flight progressed, under the gaze of the world.

For the first time in the history of the Soviet manned spaceflight programme cosmonauts were in orbit during the May Day celebrations, the major Soviet holiday. To celebrate the event the Protons became the first spacemen to be given a holiday during a flight. The rest from scientific work seems to have lasted almost five days during which the FCC worked harder than usual to free the crew from their mandatory tasks and provide them with interesting active rest days (although there was no respite from the obligatory 2 – 2½ hours per day of intensive physical exercises the men performed).

Using the two-way television link video recordings of Moscow Central TV programmes were transmitted to the crewmen. They were also able to watch the impressive demonstration in Red Square and exchanged greetings with their cosmonaut comrades and their relatives. On the eve of the holiday the two men held an impromptu news conference in which they told newsmen of the beauty of tropical storms seen during night-time orbits and the changes that spring was bringing to the surface of the planet.

Even as the holiday period progressed work was continuing on the preparation of the Progress 6 cargo spaceship. Prior to the launch of the sixth Progress the orbital complex made an unreported manoeuvre which had the effect of shifting the launch window by one day.

Progress 6 was launched at 0417 on 13 May into an initial orbit of 193 by 268 km with a period of 88.8 minutes at the nominal 51.6° inclination. Two orbital manoeuvres were completed on 13 May (no mention was made by the Soviets of any alteration to the construction of the Progress propulsion unit which is the same as that employed on the Soyuz spaceship). Three more manoeuvres were scheduled for 14 May on instructions relayed from the land-and sea-based tracking complexes. Gradually the cargo spaceship was brought into the rendezvous mode.

By 0300 on 15 May Lyakhov and Ryumin were already awake to begin preparations for the docking. About an hour later, having had their breakfast and performed their morning exercises, they assumed their positions behind the main control panel of Salyut. At this stage Progress 6 was some 30 km away and catching up fast. Soon the cosmonauts were able to see, on their TV screen, a luminous dot which became momentarily brighter – Progress 6 was firing its thrusters. Within 15 minutes of the first visual sighting the cargo spacecraft had approached to the point where its outlines could be discerned by the crew and the FCC controllers. Beacon signal lights flashed on and off constantly on the space freighter.

With the Protons controlling the orientation of the station and the FCC controlling the approach Progress 6 was commanded to a flawless automatic docking at 0619. The three spacecraft complex was in an orbit with a height of 326 x 344 km above the Earth. The crew's first task was to check the rigidity of the docking seal in preparation for opening the internal hatches.

Progress 6 delivered over 100 items to the station including the usual supplies of fuel for the ODU; water; regenerators and other equipment for the life support system; air to replace that lost from the station by dockings, venting of debris and operation of the Splav-01 airlock and food prepared to the cosmonauts' own tastes and preferences. There were also materials for new technological experiments in the Splav-01 and Kristall furnaces; a replacement part for the on-board computer; new lighting equipment for filming and TV broadcasts; a store of electric bulbs; a receiving teleprinter; biological samples, such as a single tulip which, once the crew had put it into their "greenhouse", was expected to bloom; seeds of pine trees and radishes for use in the biogravistat centrifuge; Bulgarian-made equipment for scientific research. Some of the items the cosmonauts had personally requested.

FCC advised the crew not to hurry unloading Progress 6. Apparently the crew had unloaded the previous cargo ship ahead of schedule. This time the FCC wanted the crew to adhere strictly to the timetable. As usual the first item unloaded was the personal package containing letters, newspapers and presents.

Specialists noted that unloading items was easier than loading them. Items on the cargo ships are secured so that a half-turn of a special bolt-lock is enough to release even the bulkiest items, but still rigid enough to stay attached during the rigours of launch. Specialists noted that loading used equipment back into the Progress cargo compartment was not simply a case of getting everything packed in but involved the precise distribution of the weight (or more accurately mass) to maintain the correct balance, which aided the controllers when the time came to orient the spacecraft for the destructive re-entry burn.

For their new profession of "space riggers" the Salyut 6 crews had trained at the "hydrobasin" at the Yuri Gagarin Training Centre. Aleksandr Ivanchenkov said, however, that the training procedures proved to be unhelpful during the actual flight. The Photons had worn out their gloves within a few days of the first unloading operation. The only real training, he noted, was experience accumulated during the flight. Ivanchenkov noted that it had taken Kovalenok and himself a week to unload the first cargo ship to visit the station during his tenure. By the time of the third unloading operation – Progress 4 – this period took only two days. The conclusion was simple, Ivanchenkov said; the longer one stays in space the more efficient the work becomes. Ivanchenkov said he delighted in pushing even the bulkiest items around the station with very little effort.

The standard refuelling operation was controlled exclusively by the FCC. Soviet specialists stressed that the time had not yet arrived when cosmonauts could be allowed complete autonomy in the decision making process of any mission milestone. The Protons' task therefore, during the refuelling procedure, was the "routine and monotonous" one of checking the radio transmissions from the FCC and checking the air-tightness of the fuelling manifolds, lines and joints. Following the successful transfer of fuel and oxidiser the refuelling lines were purged by a blast of nitrogen to clear out any residual liquids.

A manoeuvre, late on 22 May, using the Progress 6 engines, put the complex into a 333 x 352 km x 91.2 minute orbit. This altered the complex's ground track so that the favourable

radio-visibility passes over the USSR ground tracking network occurred during local daylight at those sites. The fact that the orbital groundtrack had precessed, so that the most favourable passes over these sites was during the night, had prompted the FCC to alter the cosmonauts' working day slightly.

The air pressure on the complex was increased on 27 May from 756 mm to about 800 mm at a rate of 13 mm/hour by pumping from a 100 m³ (80 kg), supply aboard Progress 6.

Salyut 6 observers expected Progress 6 to separate from the station on or around 31 May in readiness for the anticipated Soviet/Hungarian flight to begin at the very first opportunity for launch in the June window, 5 June. On 2 June, however, with Progress 6 still attached to the complex came a report from "Hungarian diplomatic sources" that the flight, scheduled for 5 June, had been postponed (according to the Hungarians) because of "serious troubles with the Salyut space station requiring major alterations" [15] The BBC's Moscow correspondent, Kevin Ruane, reported that "reliable Moscow sources, whilst confirming the postponement, suggest that Soviet controllers are being extra cautious following the failure of the (Soyuz 33) flight."

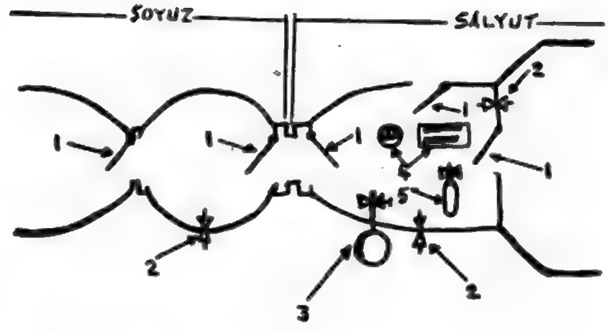
That the Soviets intended to continue the Protons' flight was evidenced by the continued experiments and repair work (the cosmonauts had only recently replaced the control panel of the 'Delta' navigation system) and orbital corrections two of which, on 4 and 5 June respectively, had placed the Salyut complex into a 358 x 371 km orbit with a period of 91.65 minutes. It was then confidently expected that the Progress cargo ship would leave the complex before the launch of the next manned Soyuz. But the very next day, 6 June, Soyuz 34 was launched, unmanned, from Baikonur beginning the most active phase to date in the Salyut 6 operations.

Preparations for Soyuz 34

Following the failure of Soyuz 33 the top Soviet propulsion unit specialists begun analysing the telemetered data from the spacecraft to isolate the fault which had manifested itself to the crew aboard as an engine shutdown 3 seconds into a 6 second burn and abnormally high vibrations in the ship. By 14 May when Rukavishnikov and Ivanov arrived in Sofia, the Bulgarian Capital, for their "victory tour" the fault had apparently been identified. Bulgarian State President Todor Zhivkov made an oblique reference to the fact when he said that "now the full conditions are known under which (the Soyuz 33 crew) worked in space ... we are still prouder of their accomplishments.',

In the Soviet workshops specialists had devised practical and theoretical models of the Soyuz 33 failure for ground test bench trials. The fault was of particular concern because in 4000 ground and space firings of the Soyuz engine design the engine had performed with 100% efficiency. Furthermore the specific defective part had functioned 8000 times during these tests without failure. To complicate matters Soyuz 33 was reportedly the most "perfect" Soviet manned spaceship ever launched. Pre-flight tests at the Baikonur MIK had revealed only 3 or 4 minor defects in systems performance during the acceptance checks from the assembly factory. Soviet specialists undertook to modernise the design of the engine system before allowing men to fly with it. The uprated design was test fired and the defective component tested separately until the specialists were confident in its ability to perform to specification.

Despite these tests, and after assessing the condition of the Soyuz 32 ferry in which the Intercosmos crew were to return home (and which had by now been in space for longer than any other Soyuz), the decision was made to postpone any further Intercosmos flight until the next long-term flight. Soyuz 34 was now scheduled to be flown as a test of the uprated propulsion system. FCC controllers were retrained for the automatic docking of Soyuz 34.



SALYUT AIRLOCK: Scheme of operation.

Key:
1. Internal and external hatches.
2. Valves for depressurisation and repressurisation.
3. External bottled supply of air and repressurisation valve.
4. EVA airlock controls.
5. Contingency bottled air supply in transfer compartment.

Sketch by the author, from an original in "Aviatsiya i Kosmonavtika"

Soyuz 34 in Flight

Soyuz 34 was launched at 1813 on 6 June into an initial orbit of 198 x 270 km; 88.9 minute period, 51.6° inclination. Telemetered data from the new propulsion system indicated that it was in order. Late in the evening the unit was fired for the first time and functioned as planned. Four such manoeuvres were planned. The Soviet press, announcing the launch, said that before Soyuz 34 was manoeuvred into an approach trajectory with the Salyut complex Progress 6 would be disconnected and steered away from the complex.

At 0800 on the morning of 8 June Progress 6, loaded with about 150 kg of used equipment, was undocked from the complex, apparently under the complete control of Lyakhov and Ryumin, who also supervised the separation manoeuvre. The systems of Progress 7 were then put into autonomous flight regime. At 1851 the next day the retro rocket of the cargo ship was activated to send it spiralling to destruction in the upper layers of the atmosphere over the Pacific ocean away from the shipping lanes.

Late on the evening of 8 June the orbital correction engine of Soyuz 34 was activated for the fourth and last time. The unmanned spaceship quickly began closing in on the manned complex. About 30 minutes prior to the link-up the Igla navigation system of Soyuz 34 was activated. Salyut was automatically oriented with the rear docking port facing the approaching transport. Soyuz's small manoeuvre engines were activated, often for as little as one-tenth of a second, during the televised link-up which was completed at 2002.

Once again the FCC advised the crew to take their time unloading the cargoes delivered by Soyuz 34. The crew were not scheduled to open the hatches of the ship until the next day. Following hatch opening, about 1200 on the 9th, the crew raised tins of currant juice inside the Soyuz 34 OM as a sign of joyful housewarming. In a press conference the crew described the docking and said they were looking forward to seeing the tulips (which were in bud) delivered by Soyuz 34 bloom. They had brought a "whiff of summer" to the station the crew admitted. The crew were to use Soyuz 34 to return to Earth during the next landing window opportunity in late August. There was still one more cargo spaceship to dock with the complex which meant Soyuz 34 had to be redocked to the front docking unit. The problem was that Soyuz 32 was still occupying the front docking unit. Soyuz 32 was to be recovered following an automatic re-entry.

In preparation for the automatic recovery the Protons were ordered to transfer some of the results of their work in orbit to the Soyuz 32 descent module. The Soyuz spacecraft has a normal return capacity of about 50 kg of results plus two crewmembers. Because Soyuz 32 was to descend unmanned specialists at FCC took the opportunity to load into the crew seats several used items from the station for laboratory analysis. Many of these items are normally destroyed in the Progress cargo compartments. Amongst the items to be returned were: watches from the central control panel which had operated for 600 hrs instead of the guaranteed 100; defective lamps; vacuum cleaner contents and used filters.

Soviet confidence in the automatic flight of the Soyuz 32 spacecraft was evidenced by the inclusion of valuable research materials including 29 ampoules obtained during smelting experiments on the Kristall and Splav-01 units; 50 cannisters containing kilometres of film from the MKF-6M, KATE-140 and hand-held cameras; many biocontainers with specimens from biological experiments including cucumbers, lettuce and radishes grown on Salyut; *Drosophila* fruit flies bred in space; results of Soviet/Bulgarian experiments and a mould of a hollow spotted by the crew on one of the docking units (and thought to be a result of a micrometeoroid impact). Total weight of the returned cargo was 180 kg. Following examination of the returned materials specialists were expected to radio to the crewmen advice and instructions for improving the quality of the observations, melts and other aspects.

At 0951 on 13 June Soyuz 32 was undocked from the Salyut 6/Soyuz 34 complex. For three circuits of the Earth the spacecraft was monitored by FCC (about 1 orbit longer than normal, indicating the extent of the checking) until, on the 4th revolution after undocking, the retro-motors were fired successfully for over 200 seconds to put the automatic spacecraft into a descent trajectory. The spacecraft's three components then separated, as normal. All portions of the re-entry appear to have been performed successfully resulting in a soft landing, at 1618, some 295 km north west of Dzezkazgan (this was not a normal landing window).[16]

Specialists were soon receiving their results of the orbital work and Soviet TV soon took the opportunity to show in-flight film of the two men performing a variety of activities including exercising and even having a haircut[17].

Soyuz 34 Redocking

The next day (14 June) was a normal launch/landing window opportunity and the Soviets took the initiative to round off a week of intense activity with the redocking of Soyuz 34. In the afternoon Lyakhov and Ryumin transferred to Soyuz 34, sealed themselves in and donned their spacesuits. At 1618 commands were given for Soyuz 34 to separate from Salyut 6. The cosmonauts then withdrew the spacecraft to a distance of about 100 m from the station and activated the mutual search and approach system of the space vehicles. Salyut 6 was then commanded to execute a 180° turn around its longitudinal axis. At this point the automatic docking system was activated. With the Protons monitoring the operation of the Soyuz the transport spaceship was commanded to approach the front docking port of the station where it redocked successfully.

One orbit later the Protons reopened the hatches and floated into the station and "shook hands in a congratulatory expression of joy."

The pace at which the two major activities occurred indicated that the Soviets were attempting to take the opportunity of launching the second scheduled Intercosmos crew for the window as planned. However, by the time the window closed on 28 June, there had been no reports of preparations for manned launches. That the Soviets intended to fly two Intercosmos crews in the same window is evidenced by the launch, on 28 June, of Progress 7 which, coming on the final day of the window, would have allowed the cosmonauts to restock the Salyut with consumables.

Progress 7

A standard A-2 carrier rocket with the Progress 7 cargo spacecraft as its payload was launched from Baikonur milliseconds past its nominal launch time of 0925 and 10 seconds on 28 June into an orbit of 193 to 270 km x 51.6°; inclination period 88.8 minutes. Following standard calculations by the FCC ballistics team to determine the most convenient rendezvous trajectory for the ship to follow Progress 7's engines were activated to raise the height of the orbit to 275 x 346 km, period 90.6 minutes. At 1118 on 30 June, following the normal sequence of manoeuvres, Progress 7 docked with Salyut 6's rear docking unit.

Progress 7 carried 1,230 kg of freight bringing the total amount of freight delivered to the Protons to 4,538 kg. Progress 7 carried about 500 kg of fuel for the ODU, over 50 kg of foodstuffs; photographic materials; clothes; equipment for the life support system; new gravity suits; indoor plants and personal mail. New scientific equipment delivered included the KRT-10 radio telescope, Vaporiser and Resistance instruments.

As a special bonus the FCC psychology team had included a book, *The Moscow Area* to remind the crew of the forests, fields and streams they said they were missing. The crew derived great pleasure from such items. They also kept an aware eye on the news and even had a political commentator brief them on the SALT 2 treaty.

As a prelude to the KRT-10 experiments, and to counteract the increased atmospheric density (which had hastened Skylab's early decay), the crew used the spare propellant left over from Progress 7's "very economical docking" to raise the height of the orbit. The manoeuvre, using Progress 7's engines, was effected over two days, 3 to 4 July. The first burn, which took place outside of the FCC radio visibility zones, lasted for 114 seconds and the second, over the USSR, lasted for 75 seconds. The resulting 399 x 411 km 92.46 minute orbit was the highest ever for a Salyut station.

It took the Protons about four days to unload the cargo ship sticking to the flight plan. The crew then reloaded the cargo compartment of the Progress with the used equipment. The station was again successfully refuelled and air was once more pumped into Salyut's compartments.

Passing the Record

At 0242 on 15 July, as they slept, the Protons passed the 139 day 14 hr 48 min flight time duration record set by the Photons and thus became the longest flying space crew. The Soviets, as usual, made several statements to the effect that breaking the record was not the sole purpose of the flight to Salyut 6 but rather was to increase the scientific return from each flight. The Soviets noted that the Protons had added some new "firsts" to the long list of Salyut 6 achievements. The crew had been the first to:

- perform regular repair and maintenance work in orbit.
- spend so long isolated from other people.
- receive TV pictures from the Earth via an on-board TV set.

Soviet specialists noted with satisfaction that the physical training and psychological support programmes had enabled the two men to keep in generally exellent health and to demonstrate great capacity for work. Their "efficiency factor" was stated to be 2 to 3 times that demonstrated on short flights. This prompted several Soviet statements to the affect that the longer the cosmonaut crews could be kept in space the greater the scientific return from these long flights would be.

Erecting a Radio-Telescope

The Protons' last month in space was particularly active, although more eventful in the end than FCC would have wished. The events began on 18 July with the deployment of a 10 m diameter wire reflector dish which formed the Cosmic

Radio Telescope (KRT-10).

The mechanical and electronic parts of the instrument were delivered aboard Progress 7 and assembled over a period of days by Lyakhov and Ryumin. For the deployment of the antenna the cosmonauts laid the mast and electronics of the KRT-10 along the axis of the large diameter portion of the working compartment and the dish, which resembled a furled umbrella, along the axis in the Cargo Compartment of Progress 7. The Soviets were not specific about how the mast was connected to the hatch of the Rear Transfer Chamber once the mast was pushed out (clearly the mast could not go through the hatch). The crew noted thankfully that assembly of the instrument was easier in space than had been the case on Earth where gravity had hampered the testing of the construction of the over 300 kg instrument. A similar instrument built to work on the Earth, the Soviets noted, would weigh many tonnes.

At 0350 on 18 July Progress 7 was automatically detached and (probably by pressure difference) allowed to drift away from the Salyut station. With FCC watching via TV transmitted from Progress 7 the commands were given to unfurl the antenna. In the words of an observer at the FCC "the familiar outlines of the Salyut station were blotted out by the huge dish of the receiving antenna."

Over the next few days the cosmonauts were to calibrate the instrument in preparation for the planned series of observations. At 0157 on 20 July, after FCC had conducted tests of its Igla (Needle) mutual search and approach system, Progress 7's engines were activated and the cargo ship plunged to its destructive re-entry over the Pacific.

Working in conjunction with a 70 metre dish at the Crimea Long-Range Space Communications Centre the cosmonauts carried out a number of important observation with the KRT-10 over the next three weeks.

Because the KRT-10 was in space, at a height of over 400 km, the separation distances between it and the 70 metre dish ranged between 400 to 10,000 km. By means of interferometry this meant that the object to be studied was observed with a radio telescope system with a sensitivity equal to that of a single telescope with a receiver the diameter of the Earth. The ground and space receivers were synchronised with very precise clocks. The KRT-10 was in use every other day probably because of the power consumption levels which required the batteries to be recharged after every day's work for a day.

In their observation programme the cosmonauts directed the telescope towards the Milky Way, the Sun, pulsar PL 0329 and deep sky sources of radio emission in order to map these sources. In addition radio measurements were made of the Earth to study meterorological phenomena, soil humidity and moisture content, salinity of water and the surface state of the ocean in a manner similar to the unfortunately curtailed SEASAT.

At the end of the observing programme, on 9 August, the KRT-10 antenna was due to be cast off to allow other spacecraft to use the rear docking assembly. However, during this operation, the structure experienced unplanned vibrations and unfortunately the mesh became entangled on protruding elements on the outside of the station (possibly an antenna or one of the nozzles of the ODU).

The Soviets stressed that the incident was treated calmly by both the crewmen and the FCC officials. After analysing the problem the Flight Controllers recommended that, in order to dislodge the antenna, the Salyut be manoeuvred forward sharply. Analysis of TV pictures returned by the camera above the docking port indicated that this would do the trick. At one stage of the manoeuvre FCC officials thought that the plan had worked but it was soon apparent that it had not. TV pictures showed the dish still attached. The Flight Controllers then decided that rocking the station around its axis might work. After the manoeuvres for this had been completed a disgruntled Lyakhov radioed "no change; think of something else!',

The, by now, obvious solution was to allow the cosmonauts to go into open space and manually "unhook" the antenna. Whilst the crew were immediately in agreement with the plan the FCC officials dithered, arguing that such an arduous task so late in the flight might involve some hazards if the crew were too fatigued. It appears that the cosmonauts were due to stand in the opened hatchway of the station and retrieve samples of materials from around the hatch, as the Photons had done, but the extra task worried the controllers. Simulations in the 'hydrobasin' at the Yuri Gagarin Training Centre, Zvyodzny Gorodok, proved the task was feasible and that the tools to do the job were on board the station. Finally the controllers relented and the necessary instructions were teleprinted up to the crew. By 15 August all was ready.

Protons Above the Planet

After donning their space suits (the same ones worn by the Taymyrs and the Photons) Lyakhov and Ryumin sealed themselves into Salyut's Forward Transfer Compartment and vented the air. It was Ryumin's job to open the hatch but almost immediately the Flight Engineer had worrisome news for the controllers: the hatch refused to budge. Ryumin applied more pressure and after a few seconds the recalcitrant hatch swung open. The time was 1416.

Ryumin floated out just in time to witness the grandure of an orbital sunset. With the EVA already behind time and the station passing through orbital darkness the cosmonauts were instructed to wait for sunrise at the hatchway. Mission rules forbade them to work during periods of orbital night-time outside the ship. The period of night lasted 36 minutes. In this period Lyakhov baulked at using the helmet's light filter in case it froze over. Although the temperature outside of their space suits was in the order of 140° C below zero the suit's thermal control system kept the crewmen at a comfortable 19 to 20° C.

The cosmonauts were struck by the beauty of the stars. "They look like huge diamond pins on black velvet", Ryumin said adding that they seemed so close that to touch one he felt he only had "to stretch out his hand to hold one in his palm."

As the station passed out of the Earth's shadow the cosmonauts were reminded that they were out in space to work. They quickly set about that task. With Lyakhov stationed at the hatch Ryumin, constantly attached to the station via a 20 m long safety line, floated gingerly along the length of the Salyut using the handrails for guidance and support. Arriving at the rear end of the station Ryumin assessed the situation, a task complicated by the fact that the Sun was shining directly into his eyes. At first the task looked difficult but after consulting Lyakhov the Flight Engineer floated down to the part of the antenna which was tangled and smartly cut it free with four quick snips of the pliers he was carrying. Ryumin then imparted velocity to the now free floating antenna (probably by means of his EVA boot) which ensured that the antenna would not return to the vicinity of the station. Visual observations from Southern England some hours later confirmed a wide separation of station and antenna. The operation, carried out outside of the radio-visibility zones, called for all Ryumin's training and skill.

Moving back to the Transfer Compartment Ryumin inspected the station's exterior noting that the portholes were covered by a thin layer of dust which he was sure could not be wiped off because the glass had been damaged by the effects of both cosmic rays and micrometeoroids. Ryumin had taken two instruments with him into open space one of which was left attached to the station's exterior and the other returned to the cabin. As Salyut returned into the FCC radio-visibility zone and it was realised that success had been achieved, the control personnel burst into spontaneous applause. Radio com-

Cosmonauts Lt-Col. Vladimir Lyakhov and Flight Engineer Valery Ryumin who spent 175 days in space last year examine results obtained with a navigational instrument.

Novosti Press Agency

munications during the EVA had been one way only Salyut - FCC.

All that remained now was for the cosmonauts to retrieve instruments of the micro-meteoroid detection systems and cassettes containing various construction, optical, thermal protection and polymer materials. One of these cassettes had been attached to the station since its launch on 29 September 1977; the other had been left there by the Photons during their EVA on 29 July 1978.

The cosmonauts then entered the transfer compartment and repressurized it. The EVA had lasted for 1 hour 23 minutes. After removing their suits they entered the major compartment of the station again. The Soviets claim that despite the late start to the EVA the cosmonauts had finished the EVA 20 minutes earlier than scheduled. The crew's judgement on their ability to perform the complicated operation had been validated. The Flight Controllers were unashamedly delighted with the results and told reporters that the cosmonauts would rest for a few days, complete some final smelting experiments and then return home.

Birthday Greetings

The next day, 16 August, was Ryumin's 40th birthday. As Lyakhov had done before him, on his 40th birthday on 21 July, Ryumin was allowed a prolonged breakfast during which he received congratulations from friends and relatives. A toast was drunk with fruit juice (of course, there was no alcohol aboard the station) after which the crewman being fêted was treated by FCC to his favourite form of cultural entertainment by radio. In Lyakhov's case this took the form of operettas.

But the day was not all play. Ballistic specialists noted that the ground-track of the station on the day of the landing would take the descent module close to the mining town of Karazhol. The cosmonauts were therefore instructed to use the engines of Soyuz 34 to trim the orbit of the complex so that the landing area would be in the normal recovery zone in Kazakhstan. The altitude, of the complex following the trim was 411 x 386 km with an orbital period of 92.28 minutes.

Near the flight's end the crew gave a short press conference for assembled journalists from the socialist countries in which they described their feelings and the experimental work they were concluding. Lastly, Ryumin thanked the workers for helping to make the flight such a success. "Success inspires one anywhere and this achievement (of almost 6 months in space) has given us fresh strength for further work," Ryumin noted.

Return to Earth

Early on the morning of 19 August (Aviation Day in the USSR) the cosmonauts loaded their final bits of baggage into Soyuz 34, ate their last meal aboard Salyut 6, closed down the systems and switched off the lights, then closed the internal hatches between the station and the Soyuz ferry that was to deliver them back to the Earth.

After donning their suits and checking the systems of the Soyuz 34 ferry, they reported to the FCC that all was ready for the undocking. FCC radioed a command to the Soyuz 34 autopilot and at about 0908 the Soyuz and Salyut parted.

In the couple of orbits that followed before retrofire the crew were addressed by Vladimir Shatalov and Aleksei Yeliseyev. The cosmonauts were advised that conditions in the recovery area were cloudy with the cloud base at about 1,000 m. The weather was good with visibility more than 20 km and a wind strength of about 5 m per second. Temperature was around 20° C.

Aleksei Leonov was in charge of the recovery HQ and he maintained regular contact with FCC. Before the landing the air corridors were closed over the target area and power workers stood by to disconnect the high tension power lines.

Following about 200 seconds of retrofire over the Atlantic Soyuz 34 separated into its three separate compartments. The descent cabin, travelling at a speed of around 8 km/sec., entered the denser layers of the atmosphere and was quickly enveloped in a dark film which covered Ryumin's window with soot. The temperature outside of the hermetically sealed cabin was in excess of 3,000° C. The cosmonauts were now subject to heavy overloads, their first meeting with gravity for 25 weeks.

Following the customary radio blackout, and with the cabin in the lower layers of the atmosphere, the cosmonauts re-established communications with the ground control staff and the recovery forces. They reported that the parachute system was working normally. At this point and up to the moment of touchdown the cabin was transmitting short-wave radio beacon

signals to the 11 aircraft and 15 helicopters tracking the descent.

A valve in the cabin opened to equalise the internal pressure with the pressure outside – a similar valve, on Soyuz 11, had opened while the cabin was still in space and had brought death to the three members of that spaceship in 1971 – bringing the first fresh air that the Protons had breathed for 175 days into the cabin.

Homing in on the signals from the module the TV helicopter found the cabin still in the air under its 1000 m² red and white parachute. Cushioned by retro rockets fired from its base at a height of only 1 metre from the ground, the cabin touched down at 1230 in an area 170 km south east of Dzhezkazgan. The Protons, flight had lasted for 175 days and 36 minutes.

The cosmonauts were soon being carried from the cabin, although Ryumin was obviously fit enough to walk, and were placed into specially designed "lounge chairs" some feet away from the cabin. There the crew were presented with a bunch of flowers each which they gratefully pressed into their faces. Ryumin was clearly in good health and was the more animated of the two.

In a short chat with a newsman the cosmonants said that they were delighted to be home.

Ryumin, noting that his body felt twice as heavy as normal, confided that he felt the Earth had given them "a not too friendly welcome!" Lyakhov agreed and stated that it was nice to be able to stamp his feet on the ground again – though with some difficulty!

Two other people glad to see the flight end were the cosmonauts' wives. Zinaida Lyakhov said that although they had been able to watch their men on TV "sometimes it had been difficult to be alone with two children. But there were always friends to help. Natasha (Ryumin) has been like a sister to me."

Whilst the Soviet leaders awarded both men the title Hero of the Soviet Union and Order of Lenin and Gold Star medals, the cosmonauts were being airlifted to Dzhezkazgan where they were given the traditional welcome of bread and salt along with sashes of honorary citizens. From there the men were flown to the Hotel Kosmanayt at Baikonur where their post-flight readaptation was to begin.

Salyut Sails on

By 22 August Salyut 6 was orbiting at 384 x 409 km with a period of 90.3 minutes. Konstantin Feoktistov told journalists in mid-September that Soviet specialists were checking the state of the station to decide on future flights. He forecast that the time was not far distant when whole teams and scientific laboratories would be working permanently in orbit.

Date	Scientific Observations	Medical Observations	Mission Milestones, Ship's Systems and Technological Experiments
May			
1		Rest day on national holiday. Saw and spoke to relatives and gave a press conference.	Watched "Earth-to-Orbit" TV of demonstration in Red Square for May Day celebration.
2		Rest day on national holiday. Continued physical exercises.	
3	Crew spotted forest fires in Soviet Far East.	Day of medical tests. Parameters of Lyakhov and Ryumin are: pulse 60 and 53; blood pressure 115/75 and 110/75.	Smelting experiment in the Kristall furnace obtains arsenide of indium.
4	Observations with BST-1M.	Biological experiments continued.	
5	Took photos of Earth's surface.	Day of active rest. Continued observing biological experiments.	
6	Continued Yelena gamma telescope observations.	Day of active rest. TV of families broadcast to station.	
7		Crew measured their body mass and assessed condition of muscle groups.	Semiconductor crystal obtained in Kristall unit.
8	Observed stars with BST-1M.	Physical exercise programme continued.	Replaced old TV transmitter with new one delivered by Progress 5. Did some preplanned maintenance work. Parameters in station's compartments: temperature: 20°C; pressure 755 mm.
9			Semiconductor cadmium sulphide obtained in Kristall.
10		Day of medical tests. Parameters of Lyakhov and Ryumin are: pulse 65 and 62; blood pressure 130/65 and 130/70.	Semiconductor indium arsenide obtained in Kristall.
11		Conducted experiment to study process of heat control in man in orbital flight.	
12	Documenting experimental work in ship's log.	Day of active rest. Watched TV, did physical exercises.	

Date	Scientific Observations	Medical Observations	Mission Milestones, Ship's System and Technological Experiments
May (Cont.) 13		Day of active rest.	Progress 6 launched at 0417.
14	Visual observations and photography of Earth's land and sea surfaces.	Day of medical examinations.	Preparing station for Progress 6 docking. Prophylactic and repair measures conducted on station's systems.
15	Crew measured noise levels in station's compartments.		Progress 6 docks at 0619.
16		Continuation of physical exercises. Crew continue to feel well.	Hatches to Progress 6 opened; crew begin transferring cargoes into Salyut. Systems of Soyuz 32 and the activation of its engine system checked.
17		Continued physical exercises.	Continued unloading Progress 6.
18		Day of medical tests. Parameters of Lyakhov and Ryumin are: pulse 60 and 62; blood pressure 130/60 and 130/65.	Replaced ventilator in Salyut's work compartment. Prepared equipment for scientific experiments.
19		Day of active rest. Listened to radio broadcasts and music; rested in the afternoon.	Completed smelting experiment to obtain a semiconductor.
20		Day of active rest. Spoke to family and friends via radio and conducted physical exercises. Music and radio broadcasts beamed to station.	
21		Biological experiments continued.	Experiment to obtain optical materials conducted in the Splav-01 unit. Completed the unloading of Progress 6 and began loading it with used equipment.
22	Measurements of gamma radiation and charged particles with Yelena instrument continued.		Transferring used items into Progress 6. Orbit of complex raised by Progress 6 engines.
23			Checked refuelling lines. Final items unloaded from Progress 6.
24			Refuelling preparations completed.
25	Studied upper atmosphere with Bulgarian-made Duga instrument.	Medical staff note that the crew are working "with great capacity and are in excellent health."	Refuelling conducted.
26	Continuation of Duga observations of upper atmosphere. Visual observations of ocean.	Further cycle of biological experiments begun.	Air pumped from bottles on Progress 6 into Salyut.
27		Day of active rest. Crew spoke to family and friends; watched variety concert on "Earth-to-Orbit" TV set.	
28	Continuation of Yelena measurements.	Day of medical tests stresses research into muscle groups.	Station's internal parameters are: temperature 20° C.; pressure 795 mm.
29	Crew spotted "plankton blooms" in ocean and used radio telescope to study cosmic rays.	Medical checks continued.	Planned orbital correction apparently postponed.
30		Continuation of "biogravistat" experiments.	"Delta" control panel replaced with new one. Soviet/Bulgarian smelting experiment begun in Kristall unit.
31	Experiment conducted to assess amount of dust on port-holes and how it affects photography, with station in gravitational stabilised mode.	Motion pictures of physical exercises made.	Soviet/Bulgarian "Pirin" smelting experiment obtains foam metals in Splav-01 furnace.

Date	Scientific Observations	Medical Observations	Mission Milestones, Ship's Systems and Technological Experiments
June			
1		Data on cosmonaut parameters telemetered to FCC during their shower.	
2		Day of active rest. Crew sent telegram to GDL, Leningrad for its 50th anniversary meeting.	"Pirin" smelting experiment conducted on Kristall unit.
3		Day of active rest.	
4	Visual observations and photography of Earth's surface.	Routine medical checks. Biological experiments on higher plants continued.	Orbital correction performed with Progress 6 engines.
5		New series of Soviet/French "Cytos" biological experiments begun.	Further correction of orbit with Progress 6 engines on crew's 100th day in orbit.
6	Experiment conducted to study dynamics of change in composition of gaseous medium in the complex.	Day of medical checks. Crew have adapted to space better than previous crews.	Soyuz 34 launched at 1813.
7			Soyuz 34 activates engines for approach to Salyut.
8	Visual observations of the Earth and Yelena measurements continued.	Continuation of biological experiments.	Progress 6 undocks at 0800; Soyuz 34 docks at 2002.
9	Continuation of Yelena measurements.	Biological experiments with samples delivered by Soyuz 34 begun.	Crew begin unloading Soyuz 34. Progress 6 retro-fires at 1851 and is destroyed in atmosphere.
10		Day of active rest. Crew met family and friends on "Earth-to-Orbit" TV. Radio and music programmes beamed to station.	Crew gave press conference.
11	Visual observations and photography of Earth's land and ocean surfaces.	Routine medical checks and physical exercises.	Unloading Soyuz 34. Soviet/Bulgarian Kristall experiment studies "diffusion of metals in weightlessness." Internal parameters of the complex are: temperature 21°C; pressure 795 mm.
12		Crew continue biological experiments including watching a tulip bloom and development of quail eggs in an incubator.	
13			Soyuz 32 undocks at 0951, land in USSR at 1618.
14			Soyuz 34 is redocked.
15	Crew catch up on technical documentation.	Physical exercises continued.	Salyut systems checked, new scientific equipment assembled. 2-day Kristall experiment to obtain gallium arsenide begun.
16	Visual observations and photography of Earth's surface.	Day of active rest.	Repairs made to certain systems of the complex.
17	Visual observations and photography of Earth's surface.	Day of active rest. 2-way TV link in operation.	
18		Day of medical tests. Crew in good health. Parameters of Lyakhov and Ryumin are: pulse 60 and 62; blood pressure 120/70 and 130/65.	Smelting experiment conducted to obtain germanium semiconductor crystal.
19			New series of materials smelting experiments begun.

Date	Scientific Observations	Medical Observations	Mission Milestones, Ship's Systems and Technological Experiments
June (Cont.) 20	Visual observations of Earth.	Biological experiments continued.	Preparing instruments and equipment for future experiments, checking systems of complex.
21	Visual observations of Earth.	"Crew maintain perfectly good relations with each other and are full of zest for life and optimism".	Preparing apparatus and equipment, checking systems.
22	Visual observations of Earth including meteorological phenomena.	Observing tulips in container.	Continuation of checks and preparations. Station's parameters are: temperature 19°C.; pressure 792 mm.
23	Conducted visual observations of Earth at their own request.	Day of active rest included physical exercises and "bath".	
24		Day of active rest included exercises and interviews with families.	Salyut completes 10,000th orbit by 1100. Crew passed congratulations to designers.
25	Photography of Earth continued.	Biological experiments continued.	Crew tested station's radio-technical apparatus.
26	Observations and photography of Earth continued.	Biological experiments on higher plants continued in the Oasis installation.	New methods of orientating the complex with optical instruments tested.
27	Studied upper atmosphere and Earth's surface with Bulgarian instruments.	Continued physical exercises.	
28	Continued Earth observations.		Replaced Salyut ventilator and measured noise levels in parts of the complex. Progress 7 launched at 0925.
29		Physical exercises continued.	Crew cleaned station and conducted Kristall and Splav experiments.
30		Day of active rest.	Progress 7 docks at 1118. 2-day Splav experiment begun.
July 1	Visual observations and photography of Earth continued.	Day of active rest.	
2		Day of medical tests show the crew's "indices" are the same as they were before the flight began. Their mood and appetite remain excellent. Parameters of Lyakhov and Ryumin are: pulse 60 and 65; blood pressure 125/70 and 120/70.	"Most of freight delivered by Progress 7 has been transferred to the station."
3	Distortion of complex's structure caused by solar radiation studied using instruments aboard Salyut and Soyuz 34 during stabilised flight.		Orbital manoeuvre using Progress 7 engines. Unloading of cargo ship continued.
4	Spotted cyclone over Caucasus mountains during Earth observations programme.		Orbital correction with Progress 7 engine places Salyut into record 92.46 min. orbit.
5	Photographed areas of Ukraine, Volga Delta, S. Urals, Kazakhstan. Plankton belt 1000 km long was reported to FCC.		
6	Photography and observations of Earth's land and ocean areas conducted. Crew caught up with their paperwork.	Experiments with biogravistat apparatus continued.	Conducted experimental spraying with Vaporiser instrument. Refuelling preparations completed. Stowing equipment.
7	Working on unspecified experiments.	Day of active rest.	Assembling new equipment.

Date	Scientific Observations	Medical Observations	Mission Milestones, Ship's Systems and Technological Experiments
July (Cont.)			
8	Observed harvests in Caspian area through clouds.	Day of active rest.	
9			Pumped air into Salyut from tanks in Progress 7. Begun loading Progress 7 with used equipment.
10		Physical training time has been increased.	Crew gave press conference.
11	Catching up with technical documentation.	Biological experiments and exercises continues.	Installing equipment delivered by Progress 7. Salyut's internal parameters are: temperature 20°C.; pressure 820 mm.
12	Resistance experiment readied for use.		ODU refuelled with propellant.
13		Day of medical checks (parameters stated as being pulse "about 60"; blood pressure "about 120/70").	
14		Day of active rest. Crew have put new eggs into incubator.	
15		Day of active rest. Crew showed "vegetable garden" on TV.	Spaceflight longevity record passed at 0242.
16	Tested 'Vaporiser' instrument and made measurements with the Yelena telescope.	Cytos and Biogravistat experiments continued.	Tanks of ODU replenished with oxidizer.
17	Visual observations of oceans, studies under Soviet/Bulgarian programme continued.		ODU refuelling completed.
18			Progress 7 undocks at 0350. KRT-10 antenna deployed.
19		Physical exercises programme continued.	Igla system of Progress 7 tested. KRT-10 prepared for experimental work.
20	Conducted visual observations of Earth for agricultural specialists.	Conducted physical exercises and monitored biological experiments.	Crew cleaned station. Progress 7 deorbited at 0157.
21	Continued Earth observations for agricultural specialists. Crew caught up with their technical documentation work.	Day of active rest.	Continued tidying station. Lyakhov celebrates his 38th birthday.
22	Spotted typhon forming between USA and Hawaii.	Continuing biological experiments.	Adjusted KRT-10 and made first experimental observations. Day of active rest postponed to work on KRT-10.
23		Day of active rest. Spoke to family and friends, did physical exercises.	
24	Photographed Eastern USSR for minerals prospecting		Experimental programme on KRT-10 begun.
25	Photography and (unspecified) observations conducted.	Day of medical checks. Wheat planted in "Oasis" installation.	150th day of flight.
26		Cosmonauts' health continues to be good.	
27	KRT-10 observations of Milky Way, Sun and Earth made.	Continued physical exercises.	Stations's parameters are temperature 20°C.; Pressure: 820 mm.
28		Day of active rest; crew have shower. "Crew's productivity is increasing".	

Date	Scientific Observations	Medical Observations	Mission Milestones. Ship's Systems and Technological Experiments
July (Cont.) 29	KRT-10 observations continued.	Day of active rest postponed.	
30	Caught up with paperwork.	Day of active rest; physical exercises continued.	Kristall experiment begun to obtain indium antimonide monocrystal.
31	KRT-10 directed towards Earth to study ocean surface state, soil humidity and weather.		Kristall experiment completed; new one to obtain cadmium sulphide semiconductor begun.
August 1	Worked with 'Vaporiser' instrument.	Studied dynamics of change in gaseous composition of the station's compartments. After medical check Lyakhov's and Ryumin's parameters are: pulse 60 and 55; blood pressure 135/60 and 130/60.	Kristall experiment obtained germanium monocrystal.
2	Worked with KRT-10.		Continuing technical work.
3	Observed Earth, pulsar with KRT-10. Used 'Vaporiser' experimental equipment.	Continued biological experiments.	
4		Day of active rest. Biological experiments continued.	
5		Day of active rest.	
6	KRT-10 observations of Earth.	Descent Programme using the Chibis vacuum suit begun.	Kristall experiment obtains large monocrystals of indium antimonide. Parameters of complex are temperature 21°C; pressure 808 mm.
7		Continued descent programme with Chibis suit.	
8	Geophysical observations.	Continued descent programme with Chibis suit, physical exercises.	Kristall experiment obtains indium antimonide
9			Kristall experiment obtains monocrystal of gallium arsenide. Splav experiment obtained superconductor niobian aluminium, germanium and antimonide of indium, zinc and tellurium. Crew hold press conference. Attempt to jettison KRT-10 fails.
10	Crew begin loading experiments into Soyuz 34.	Descent programme continued.	
11		Day of active rest. Reported on biological experiments.	
12	Working on technical documentation.	Medical tests show pulse 60 and 61; blood pressure 130/60 and 135/60.	
13	Working on technical documentation.		Checking station's systems. Obtained gallium arsenide and indium antimonide in Splav and Kristall units.
14	Transferring results of experiments to Soyuz 34.		
15		Descent programme with Chibis suit continued.	EVA frees trapped KRT antenna.
16	Loading Soyuz 34 with results	Descent programme with Chibis suit continued.	Ryumin celebrates 40th birthday. Orbital trim puts complex into 92.28 minute orbit.
17	Loading Soyuz 34 with results.	Descent programme with Chibis suit continued.	Splav and Kristall experiment obtain germanium and indium arsenide.

Date	Scientific Observations	Medical Observations	Mission Milestones, Ship's Systems and Technological Experiments
August (Cont.)			
18	Checking Soyuz 34 systems and loading final experiment results aboard.	Descent programme concluded.	
19			Crew undock Soyuz 34 and land after 175 day 36 minute flight at 1230.
22			By 1000 Salyut 6 completes 10,920 orbits. Orbital parameters are now 384 x 409 km; period 92.3 min.

THE LONG FLIGHT IS OVER. Vladimir Lyakhov and Valery Ryumin, after landing in the Soyuz 34 capsule, are taken from the cabin and placed in special chairs to ease their rehabilitation. In the background recovery teams have erected a double-walled inflatable tent for preliminary medical examinations.

Novosti Press Agency

REFERENCES AND NOTES

15. A manoeuvre, planned for 29 May, was apparently cancelled following the postponement of the Hungarian flight. The higher orbit resulting from the Jun 4/5 burn indicates that the Soviets were "buying time" for a further attempt at docking should Soyuz 34 have failed or, with the ODU main engine apparently unusable following the fuel leak, the docking of a Progress ship to deorbit the station over the Pacific after the end of the current flight. The burn also had the effect of putting the station back onto the nominal launch window timetable.
16. Soyuz 32 was recovered on the same day as the planned Hungarian flight was probably scheduled to end lending support to the argument that two Intercosmos missions from Hungary and Cuba were to be flown to the Protons. Analysis of the launch/landing windows indicates that the timetable could have been:
Soyuz 34 (Soviet/Hungarian crew) launch 1837 Jun 5; recovery approx 1528 Jun 13. Soyuz 35 (Soviet/Cuban crew) launch about 1436 Jun 15; recovery about 1128 Jun 23. Commander for the Hungarian flight, probably is Valeri Kubasov. Viktor Gorbatko may be the commander for the future Soviet/Mongolian flight.

[To be continued]

COSMOS 146 AND 154

An analysis of two historically important space missions

By Sven Grahn and Dieter Oslender

Introduction

The flights of the two Soviet spacecraft Cosmos 146 and 154 in March and April 1967 have always been obscure with respect to both purpose and mission profile. Several authors have speculated about the purpose of these missions. The two main theories advanced so far can be summarised in the following way:

Table 1: Launch times and initial orbits.

Spacecraft	Launch date	Launch time	Inclination (deg)	Perigee km*	Apogee km*	Period min*
Cosmos 146	March 10, 1967	1300 Z	51.44	177	296	89.20
Cosmos 154	April 8, 1967	0910 Z	51.3	183	223	88.50

* *Initial orbit.*

- Both flights were near lunar velocity Earth-orbit re-entry tests of an unmanned prototype of the Zond manned circumlunar spacecraft [1]. As support for this hypothesis the fact that some of the objects resulting from these launches disappeared from orbit within one and two days respectively is often cited.
- Both flights were unsuccessful circumlunar tests of the Zond craft. According to this theory the Earth-orbit escape manoeuvre failed [2].

The following account analyses the flights of these satellites using available orbital data and amateur radio observations made in Europe at the time. An attempt is made to clarify the obscure mission profiles of these spacecraft and various new hypotheses of the nature of these flights are discussed. These partly contradict the afore-mentioned speculative classifications.

Cosmos 146

Three or possibly four objects were associated with the launching of Cosmos 146 as shown below:

Spadats no.	*Lifetime*
—	1 day?
2815	1 day
2705	8.3 days
2709	8.7 days

These lifetimes have been obtained from NORAD decay notes. The two objects decaying within one day have earlier been considered the main objects, but a close look at the orbital history and radio tracking data made available recently shows that one of the longer-lived objects, probably 2705, was the main object.

Figures 1 and 2 show the orbital period and heights (above a sphere of radius 6378 km) for object 2705 which seems to have manoeuvred extensively during the first 2.5 days of the mission. A smaller disturbance in the natural decay pattern, possibly indicating a manoeuvre, is seen 4.5 days after launch.

Bulletin 1 of the object 2709 was issued 2.5 days into the flight which could indicate that the appearance of this object was associated with the termination of manoeuvres at this point.

Signals from one of the objects associated with this launch were reportedly received by two sources, Oslender in Bad-Godesberg (Federal Republic of Germany) and the now-defunct tracking station of the East German Astronautical Society (DAG, Deutsche Astronautische Gesellschaft), Junge Welt (Young World) in Berlin. In DAC-bulletins [4] from 1967 Cosmos 146 was reported to have been picked up regularly up to and including the morning of 18 March 1967. According to a note in the DAG-bulletin [4] written by its editor, Mr. Karl-Heinz Neumann, Cosmos 146 was initially reported (by ADN) to be transmitting on 19.995 MHz but later corrected to 20.008 MHz by TASS, which was the frequency on which Junge Welt tracked this satellite.

Oslender's tracking log also shows that signals from a possible space object were regularly received on 20.008 MHz ten times during the period 11-15 March 1967. A comparison between these reception times and the over-the-horizon passage of objects 2705 and 2709 in Bad-Godesberg shows fair agreement (Fig. 3) of a kind often experienced later during Soyuz flights which also still use this frequency. The long reception times and command-off of the signals when the spacecraft reaches Europe resembles the procedure used for the shortwave transmitters on early Soyuz and Soyuz-type unmanned missions. The shortwave transmitter is mainly used to obtain housekeeping telemetry during periods when line-of-sight contact with Soviet tracking stations is impossible.

Oslender's and DAG's reports of signals are completely independent sources and therefore tend to support each other. Object 2705 or 2709 could be the source of the signals. Before 000 Z on 13 March it seems that these two objects were joined together during the extensive manoeuvring period of the mission.

In summary the mission of the main Cosmos 146 object can

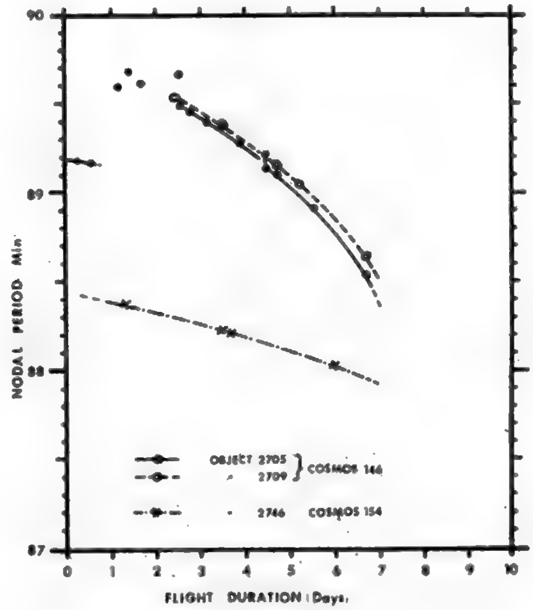


FIG. 1

Fig. 1. Orbital period of objects associated with Cosmos 146 and 154 as a function of flight duration.

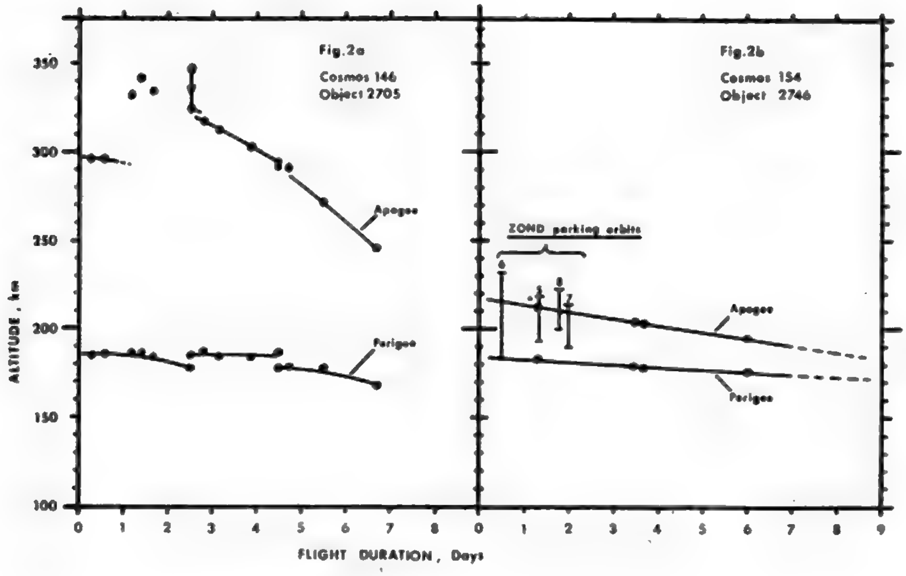
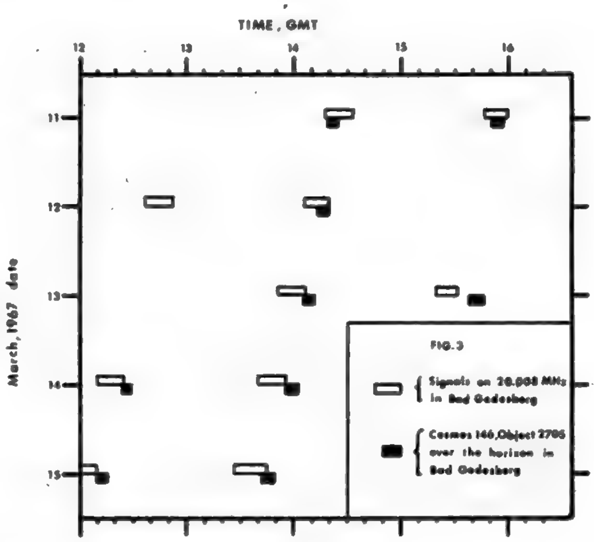


Fig. 2, left. Orbital altitudes of objects associated with Cosmos 146 and 154 as a function of flight duration.

Fig. 3, below. Observations of telemetry signals on 20.008 MHz and over-the-horizon passes of Spadats object 2705 in Bad Godesberg.

be described by the following table:

Orbit: 185-350 km (max. eccentricity)
Manoeuvres: Yes, for 2.5 days
Lifetime: 8.3 or 8.7 days
Frequency: 20.008 MHz



Cosmos 154

Four objects have been associated with the launching of Cosmos 154. According to NORAD decay notes the following table describes the lifetime of these objects:

Spadats no.	*Lifetime*
2745	2 days
2746	10.97 days
2747	2.3 days
2748	1 day

The most accurately known decay time is that of object 2746 which is given as 1221 Z ± 5 minutes on 19 April 1967 at which time the spacecraft was at approximately 50°N, 30°W, i.e. over the Atlantic Ocean. Whether or not this represents a natural decay or an intentional ocean-recovery is not known.

In Figures 1 and 2 the available information about orbital period and altitudes for object 2746 is shown. No signs of in-orbit manoeuvres can be detected for this object. The orbital altitudes for objects associated with Zond 5-7 launches and so-called "launcher rocket" in the RAE table of Earth Satellites [5] are shown in Fig. 2b.

The radio tracking log of Oslender's listening post in Bad-Godesberg for 10-13, April 1967 shows eight receptions of signals on 19.995 MHz attributable to Cosmos 154. A comparison between the reception times and the periods when object 2746 was above the local horizon in the Bad-Godesberg area (Fig. 4) shows excellent agreement.

No notes as to the signal character are available in Oslender's log. However, a hitherto unidentified reception of FSK-PDM* signals on 19.995 MHz made in Stockholm, Sweden by Grahn early on 12 April 1967 can probably be attributed to object 2746. This strong, almost "line-of-sight-strength", transmission lasted for about 7.5 minutes and occurred between the signals from the penultimate and recovery revolutions of Cosmos 153, which also transmitted FSK-PDM on 19.995 MHz. The fact

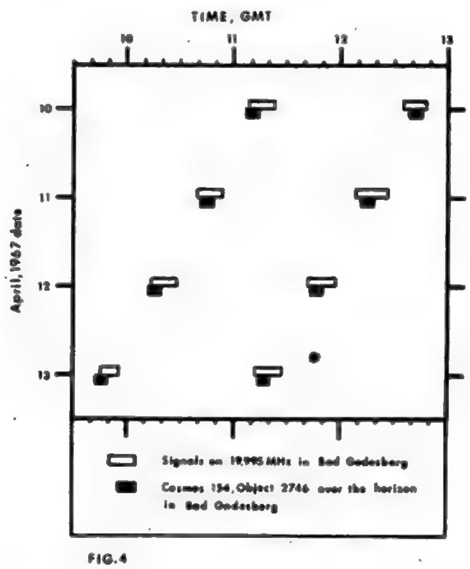


Fig. 4. Observations of telemetry signals on 19.995 MHz and over-the-horizon passes of Spadats object 2746 in Bad Godesberg.

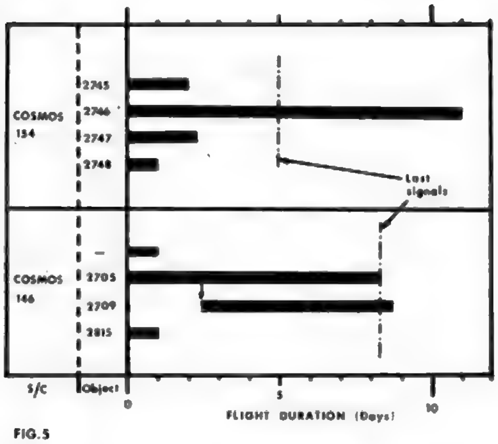


Fig. 5. Lifetimes of objects associated with the launches of Cosmos 146 and 154.

that no note as to signal character was made in Oslender's log also tends to indicate that the signal was of an ordinary and well-known nature and therefore did not need special mentioning.

The Cosmos 154 mission was probably mainly carried out by object 2746, which can be described in the following terms:

Orbit: 185-215 km (max. eccentricity)
Manoeuvres: No
Lifetime: 10-97 days
Frequency: 19.995 MHz (FSK-PDM)

Comparison between Cosmos 146 and 154

The collection of objects associated with each launch and their corresponding lifetimes are shown in Fig 5 and display distinct differences between the two missions. The flight profiles and other characteristics of the long-lived objects of each mission which transmitted shortwave signals given earlier are summarised below:

Table 2: Comparison between Cosmos 146 and 154.

Spacecraft	Object no.	Max. eccentricity Orbit	Manoeuvres	Frequency	Lifetime
Cosmos 146	2705 or 2709	185-350 km	Yes, for 2.5 days	20.008 MHz	8.3 or 8.7 days
Cosmos 154	2746	185-215 km	No.	19.995 MHz (FSK-PDM)	10.97 days

This table shows marked differences between the two missions, in fact no real similarity at all except possibly for the perigee altitudes. Also, these two objects must have possessed radically different densities. They had approximately the same perigee, but Cosmos 146, despite its higher apogee decayed much more rapidly (see Figs 1 and 2). Therefore Cosmos 146 (either of the objects 2705 and 2709) was obviously much less dense than Cosmos 154 (object 2746).

We must therefore conclude that it appears that Cosmos 146 and 154 were launched on two different missions.

Conclusion

In view of the fact that Cosmos 154 had orbital parameters close to those of the Earth parking orbits of later Zond launches (see Fig. 2b) it is tempting to assume that this mission represents in some way an Earth-orbital test flight of the Zond space vehicle. On the other hand the orbit of Cosmos 154 also resembles that of Soyuz 1. Its frequency (19.995 MHz) does not agree with that of Soyuz but with that announced for Cosmos 133, often regarded as the first Soyuz precursor.

Cosmos 146 on the other hand, showed extensive manoeuvreability and used a typical Soyuz frequency. It is therefore not unnatural to consider the possibility that this flight could represent a thorough flight test of the Soyuz propulsion system in preparation for the Soyuz 1 flight five weeks later. However, the notion that Cosmos 146 is a Soyuz precursor contradicts a generally held opinion that Cosmos 146 was a large object launched by a D-vehicle not used for Soyuz-type payloads [3].

These theories are offered here for what they are, hypothetical speculations. Nevertheless, it seems likely that Cosmos 146 and 154 carried out missions of different nature. Such a conclusion is in contradiction to earlier theories as to the nature of these very obscure but historically important spacecraft.

Acknowledgement

The authors are greatly indebted to Dr. D. G. King-Hele, Space Department, The Royal Aircraft Establishment, Farnborough, for assistance in obtaining orbital data and decay notes for Cosmos 146 and 154.

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... Both Cosmos 146 and 154 combined trans-escape fourth stages and Zond craft left Earth orbit within one day in the case of Cosmos 146 and within two days for Cosmos 154 ...
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* *FSK-PDM: Frequency-shift keying, pulse-duration modulation.*

THE PULSAR PLANET

By Geoffrey Hugh Lindop

Introduction

It has long been recognized that radio signals intended for local, national or global communications will also stray into space and they may be received by some form of extra-terrestrial intelligence(ETI). Conversely ETI may also spill some of their communications into space and these may be received by diligent observers on Earth. The earliest observations for ETI signals were carried out by Dr. Frank Drake as long ago as 1955 [1], but the first recognized study was carried out by Drake in 1960 using the 85 ft (26 metre) radio telescope of the National Radio Astronomy Observatory, Green Bank, West Virginia. Regretably no such signals were observed. Similar observations have been conducted both in the USA and the Soviet Union. Perhaps the most ambitious attempt in the Search for ETI signals(SETI) is envisaged as Project Cyclops of which much has been written [2], [3], [4].

Although Project Cyclops is still awaiting approval, a start has been made by NASA by Dr. John Billingham's use of the Arecibo Radio Telescope in a survey during 1979 of 250 stars within 100 light years of the Sun. The need to survey so many stars at a wide range of frequencies limited the observing time to only 10 minutes per star. Naturally, if the ETI for some reason had a break in transmission for this period then Billingham would not observe them.

Other researchers have attempted to transmit specific signals to ETI, the most famous example being in November 1974 again using the Arecibo Radio Telescope [5]. Numerous other authors have also contributed in the pages of *Spaceflight* to various schemes for CETI. Most projects involve a dedicated facility with the attendant high costs but Michael E. Poole has suggested that ground stations for Intelsat satellites might be used as CETI beacons [6].

The Madley Transmissions

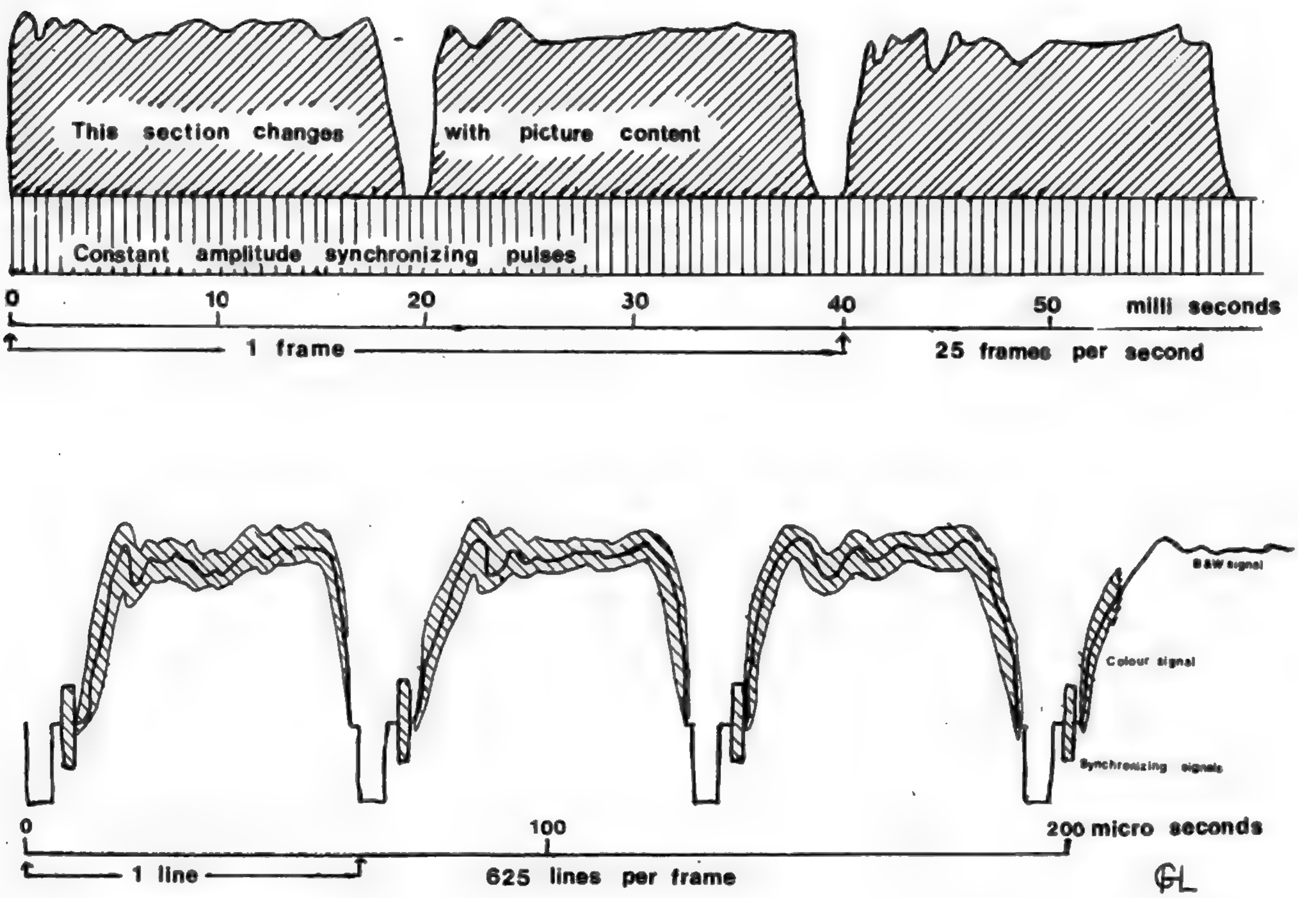
Aerial 1 at the Madley ground station, located near Hereford, England, is primarily assigned to transmissions to and from the Intelsat communications satellites over the Indian Ocean. On October 27th 1978, Michael Poole was at the station as part of a team of engineers engaged in testing the equipment and between 13.00 and 15.00 GMT on that day they transmitted a high power signal into the zenith.

The signal was beamed to all stars within the range:

Right Ascension: $15^h\ 09.8^m$ to $17^h\ 10^m$
Declination: $+52°\ 02'$ to $+52°\ 17'$

Three bright stars are in this zone, *Beta Draconis* at 363 light years; *16 Draconis* at 297 light years; and *17 Draconis* also at 297 light years. *Beta Draconis* is a star similar to our Sun (spectral type G2) and is therefore a likely star to have a planetary system around it.

Unfortunately the beamwidth being only 0.11° means that any ETI in that system will only see a pulse of radio energy lasting 22 seconds due to the rotation of the Earth. Their short duration renders them practically impossible to receive. Furthermore if ETI happens to pick them up there will be no



Typical television waveforms.

follow up, since the Madley ground station is no longer pointing to that part of the sky. However, now that Madley is operational, the microwave beam sweeps out its signals over a complete circle encompassing more stars, and furthermore ETI will see the signals as a 22 second pulse every 23 hours 56 minutes.

It is difficult to calculate exactly which stars will be able to receive transmissions from Madley due to variations in pointing angles caused by atmospheric refraction and orbital deviations of the satellites, but Table 1 is a list of candidate stars down to a limiting magnitude of 6.25 visual.

Precession will move the beam onto other stars eventually, but with the beamwidth of 0.11° from Madley, a particular star will see the terrestrial signal for a period of 20 years or so. As Michael Poole has said, the beam will be circularly polarised and as such an obviously artificial signal at a frequency in the quiet region of the cosmic noise that our own CETI investigators are using to listen on.

An ETI might put a spectrum analyser on the Madley signal and learn that it is composed of a number of channels, but would be unable to understand most of the information on any particular channel because 22 seconds is not a meaningful time scale. How much, for instance, would we gain from eavesdropping on a telephone conversation for that period?

CETI TV

The television signals being carried by Intelsat might be more informative. There are three components to a television signal. The monochrome picture information is an analogue waveform, the voltage of which is directly proportional to the instantaneous brightness of a picture element (the smallest part of a scene which can be transmitted). The picture elements are arranged like characters on a printed page. At the end of one line, information has to be transmitted to instruct the cathode ray beam in the receiver (and the scanning beam in the camera tube) to flyback to the start of the next line down. At the end of the frame, which is equivalent to the last line on a printed page, another signal has to be transmitted to tell the scanning beam to go to the top and start again. These two types of signal, known as synchronising signals, are negative pulses which in terms of the analogue picture signal are blacker than black so do not show up on the screen. A single pulse marks the end of a line but a more complex pulse chain marks the end of a field.

Aerial 1 at the Madley ground station in Hereford, England.

Post Office

The third component is the colour signal which is a very high frequency superimposed on top of the monochrome picture signal.

Table 1 Candidate Stars from Madley (Indian Ocean Station)

Star	Right Ascension	Declination	Spectral Type	Distance (light yrs)
GC 2941	2h 24m	−20° 16′	K2	172
GC 5055	4h 24m	−20° 29′	A0	181
GC 5592	4h 32m	−20° 01′	K0	
GC 6142	4h 59m	−20° 07′	B9	816
Beta Leporis	5h 26m	−20° 47′	G2	
GC 7997	6h 13m	−20° 15′	K0	
GC 8099	6h 16m	−19° 56′	B3	
12 Canis Majoris	6h 44m	−20° 57′	B8	117
15 Canis Majoris	6h 51m	−20° 09′	B1	
17 Canis Majoris	6h 53m	−20° 22′	A2	326
Pi Canis Majoris	6h 53m	−20° 04′	F2	
GC 9224	6h 58m	−20° 05′	B8	49
GC 11393	8h 19m	−19° 55′	G0+A3	96
GC 17108	12h 30m	−19° 31′	A5	
55 Virginis	13h 11m	−19° 40′	G6	970
57 Virginis	13h 13m	−19° 41′	K1	
GC 20834	15h 28m	−20° 38′	A2	544
Lambda Librae	15h 50m	−20° 01′	B3	
GC 21420	15h 55m	−20° 50′	B5	
Beta Scorpii	16h 02m	−19° 40′	B3	
Omega 1 Scorpii	16h 04m	−20° 32′	B1	
Omega 2 Scorpii	16h 04m	−20° 44′	G2	218
Psi Ophiuchi	16h 21m	−19° 55′	G9	272
Eta Capricorni	21h 01m	−20° 03′	A4	93
27 Capricorni	21h 06m	−20° 45′	F1	126
Phi Capricorni	21h 22m	−20° 22′	K0	326
37 Capricorni	21h 30m	−20° 18′	F2	102
Epsilon Capricorni	21h 34m	−19° 41′	B5	466
GC 30396	21h 40m	−19° 51′	A8	326
98 Aquarii	23h 20m	−20° 22′	K0	131

In the above table GC is an abbreviation for the Boss General Catalogue

If ETI has managed to separate the television signal from the rest of the telecommunication traffic – a process which is not unduly complicated – then the television signal will be distinctive.

Of course it is easy to decode anything if you already know the key, but even so the synchronizing pulses stand out so well, and they are such a regular pattern that I am sure the pictures could be reproduced by the receiving intelligence in black and white. Colour may present them with a more complicated problem which may not seem so straight forward, but having once received pictures they may be tempted to experiment further.

Due to the 22 second limitation on the signal reception, only a limited number of pictures will be received at any one time, but because of the very high picture rate (25 pictures per second in Europe, 30 pictures per second in USA) 550 or even 750 pictures may be received. Despite the nature of the programme, this will be sufficient to convey that we are humanoid, and illustrate our speed of movement. They may be fortunate to glimpse some of our scenery, and even if they simply see the closing credits of a programme they will understand something of our alphabet and the way we communicate in words. The mind boggles as to what they would make of Tom and Jerry! Fortunately, cartoons are not part of the normal intercontinental television traffic. ETI may however, eavesdrop on engineering test signals which are transmitted prior to the programme. These will tell little of our culture, but might be useful in decoding our television system.

The satellite capacity is rarely used to the full, and it is technically possible to use this spare capacity to transmit a 20 second CETI signal which would be in a much simplified format to TV. The CETI signal itself could take the form of a key to decode the television signals. It is also possible to pre-record a CETI programme whereby the signal could be changed automatically.

The method would be to have two Video Cassette Recorders each holding a sixty minute cassette. One hundred and sixty periods of 22 seconds can be recorded on each cassette. During each period a 20 second CETI message could be transmitted leaving the rest of the time blank to make sure that the ETI can receive the full message before the beam sweeps away. A further 160 messages can be recorded on the other machine.

At the end of the tape a device automatically changes the output from one machine to another, however, a suitable delay will occur between the second machine starting to allow for the rotation of the Earth. The first machine then automatically rewinds and takes up the transmission when the second machine has finished playing, after another suitable delay. If the delays are worked out correctly an ETI will receive the first CETI signal the first day and the second CETI signal the second day, and so on until all 320 signals have been received. Then the sequence will start all over again. Twice during the period of 320 Earth-days no signal will be received at all because of the delays in starting both machines, since it is preferable to lose such information rather than transmit a partial message during one of the tranmission windows.

Using this method more CETI information can be transmitted than by conventional CETI methods and at a fraction of the cost. At a rough estimate one such system would cost between £500 and £750. If one system was installed in each Intelsat ground station the cost would be around £100,000. This assumes no charge for satellite time. The only problem to be overcome is to gain the acceptance of INTELSAT and the national telecommunication authorities who operate the ground stations!

How Many Stars?

If all the ground stations carry such signals, then assuming a 0.11° beam width for them all, about 11° of the sky can be covered. A greater proportion could be achieved by using ground stations of a non-Intelsat organization such as Interim Eutelsat and the Orbita network in the Soviet Union.

Table 2 Candidate Stars from Goonhilly (Atlantic Station)

Star	Right Ascension	Declination	Spectral Type	Distance (light yrs)
Xi Phoenicis	00h 39m	−56° 47′	FO	
GC 2030	01h 38m	−56° 27′	K2	59
GC2821	02h 18m	−56° 10′	K5	
Chi Pictoris	05h 21m	−56° 11′	B9	
Gamma Pictoris	05h 49m	−56° 11′	K1	218
Upsilon Pictoris	06h 22m	−56° 21′	A0	
GC 8459	06h 29m	−56° 49′	G8	816
GC 9368	07h 03m	−56° 40′	A0	
GC 12138	08h 45m	−56° 35′	B3	544
GC 12303	08h 52m	−56° 28′	B9	
GC 13527	09h 47m	−56° 10′	K0	
GC 14960	10h 50m	−56° 58′	B9	181
GC 17003	12h 26m	−56° 08′	K0	218
Gamma Crucis	12h 28m	−56° 50′	M4	
GC 17352	12h 43m	−56° 13′	B5	
Mu 1 Crucis	12h 52m	−56° 54′	B3	
Mu 2 Crucis	12h 52m	−56° 54′	B3	
GC 17540	12h 53m	−56° 34′	09	
GC 19199	14h 11m	−56° 51′	B3	
GC 19318	14h 17m	−56° 09′	B7	
R Area	16h 36m	−56° 54′	B9	
GC 23217	17h 10m	−56° 50′	K5	
GC 23449	17h 19m	−56° 29′	K0	
Gamma Arae	17h 21m	−56° 20	B1	
GC 24906	18h 13m	−56° 02′	B5	
Nu Telescopii	19h 44m	−56° 29′	A5	233
Alpha Pavonis	20h 22m	−56° 54′	B3	11
Epsilon Indi	22h 00m	−56° 59′	K5	

In the above table GC is an abbreviation for the Boss General Catalogue

However, keeping it just within Intelsat, the CETI coverage is quite large although the actual number of stars is difficult to determine.

In Tables 1 and 2 candidate stars which should receive the signals from Madley and Goonhilly are listed down to magnitude 6.25 (visual). The distances of the stars within 1,000 light years of the Sun are given, but exactly how far the signals will be detectable depends on such unknown factors as the sensitivity of the ETI equipment. An arbituary limit may be set, such as the point at which the magnitude of the signal is equal to the magnitude of the 3K background radiation, but it is conceivable that ETI may be able to distinguish signal levels below this noise threshold.

In the survey I have just completed the limits I have worked to are 100 light years. In a critical case it would take 200 years for an answer to be received. A period longer than this would probably mean that we would have forgotten the question!

The tables show that three such stars are within range of Madley and two from Goonhilly. Naturally there are more stars than this within range, but below the 6.25 magnitude limit of my survey. A more thorough survey down to magnitude 21 would be very time consuming since the parameters of about 890 million stars would have to be analysed, but an estimate can be made using figures given by Spencer Jones [7].

On average it can be said that for every star above magnitude 6 (visual) there are 220,000 above magnitude 21 (photographic). However, I am not at all sure that we can assume that such a high proportion of faint stars can populate the region within 100 light years of the Sun. Mattinson has drawn up a list of stars within 20 light years of the Sun and the faintest in this list is around magnitude 15 (visual) with one notable exception at 18.6 [8], [9]. Using the magnitude 15 limit, 24,000 stars are estimated to be within range of Madley and 16,000 from Goonhilly.

Naturally a sample from only two stations is unlikely to be accurate and I am hoping in the future to extend my survey, but as an initial assessment it can be said that each Intelsat ground station is capable of transmitting to 20,000 stars within 100 light years of the Sun, and that if CETI signals were transmitted from all such stations 2 million stars can be reached.

Other Stations

Madley and Goonhilly each have dish aerials approximately 30 metres (100 ft) in diameter, and there are over 100 such stations throughout the world. A smaller number of Intelsat ground stations, known as standard B, have aerials approximately 11 metres (35 feet) in diameter, and whilst they are not as powerful, they have a beamwidth of 0.3°. The CETI signal could therefore be much longer (72 seconds).

Large steerable radio telescopes, like Jodrell Bank, cannot operate in high winds and during such periods the telescope rests pointing towards the zenith. It would be possible to use the telescope during such times to transmit a CETI signal using the same automatic technique described above. At a frequency of 1420 MHz (the famous water-hole used by CETI researchers) Jodrell Bank would have a beamwidth of about 0.2° and the CETI signal would last 48 seconds but at this frequency the signal would not be as "powerful" as a 30 metre aerial working at 6 GHz.

Reception

It seems logical to me that the main effort in searching for ETI signals from space should be devoted to those areas of the sky which are receiving the full blast from our ground stations, particularly in the early stages of Project Cyclops when the full array will not be available.

I would also suggest that in addition to the Cyclops experiment, monitoring of the sky could be achieved with the ground stations serving communications satellites in their receive mode. They offer the advantage that they are constantly tuned into the same band of sky. The CETI receiver would obviously be tuned to avoid the main beam frequency from the satellite but would provide a reasonably wide band of frequencies to be monitored in the quieter parts of the electromagnetic spectrum where most authorities agree is the best place to look for such signals. Analysis of the signals would be a significant proportion of the cost, even when sophisticated electronic systems are used to scan for signs of pattern recognition, but the cost could be reduced by using amateur observers. This is one particular field where the British Interplanetary Society could make a contribution!

Lie Low

Many people may wonder whether or not a CETI beacon in any form is desirable. Brought up on a diet of Science Fiction stories it seems that the last thing we want to do is advertise our existence to some alien culture who might exterminate us. Nevertheless, the radio beams from ground stations are going into space. If the ETI is advanced enough it will decode our signals and derive the information anyway.

It would surely make sense to send additional signals to make their task easier and ensure that we get a reply. Communication is a two fold process whereby they learn about us, but we learn about them, and in doing so take a few short cuts to progress.

Acknowledgement

The author would like to acknowledge the help and advice given by Michael Poole in the preparation of this article, and for suggesting the use of Intelsat-type ground stations for a CETI programme in the first place.

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SATELLITES IN THE CLASSROOM

The entire text of the monograph *Using Satellites in the Classroom: A Guide for Science Educators* by Dr. Martin Davidoff (*JBIS* September 1979) is now available on three microfiche cards for $1.45 dollars postpaid through a non-profit distribution agency.

Orders should be sent to ERIC Document Reproduction Service, Box 190, Arlington, Virginia 22210, USA. *Quote Document* ID

Title: *Using Satellites in the Classroom: A Guide for Science Educators*, 1978, 234 pp. Author: Davidoff, Martin R. *Document No:* ED 162 635 Micro Fiche. *Cost:* $0.83 (document charge). $0.62 (airmail postage to UK). $1.45 (total, US funds).

Dr. Davidoff tells us that the 1,200 hard copies printed have all been distributed. Approximately 250 of these went to the UK in response to mentions in *Spaceflight* and *Radio Communication*.

The material was prepared for science teachers unfamiliar with satellite systems and focuses on the AMSAT series of spacecraft.

THE BIRTH OF THE MECHANICAL SPACEMAN

THE TELEOPERATOR RETRIEVAL SYSTEM

By Gerald L. Borrowman

Introduction

The movie, "2001, A Space Odyssey" depicts a space manipulator, computer and space station engaged in a complex scientific inspection of an orbiting satellite.

The third decade of space exploration will witness the birth and use of mechanical spacemen – the unmanned remote manoeuvring teleoperator. By definition, a teleoperator is a dexterous machine with an onboard or remote control system with man in the control loop in an operational or supervisory capacity.

In the late 60's, as a result of reduced funding, NASA was forced to explore viable, low-cost means of reducing the need for extensive extravehicular activities, and the man-rating of spacecraft for future space missions which might be too hazardous to be performed by man. In this respect, remote controlled teleoperator systems offered great potential for extending the arms, hands and intellectual power of man through the distance and environment of space.

The teleoperator can perform in a variety of environments, including Earth orbit, in lunar and planetary orbits. It can operate near to the surface of galactic bodies. The teleoperator does not care whether its environments are hospitable or hostile to man as long as it is appropriately designed to function in the existing environment.

As the result of an intensification of interest in teleoperators by NASA in early 1970 a Task Team of scientists and engineers was convened. The team headed by NASA's Dr. Stanley Deutsch recommended that space agency begin an immediate coordinated integrated programme of teleoperator research and technology development, and, that a state-of-the art system be built and flown as soon as possible. Development of a teleoperator system entailed investigations of performance and design parameters that include man machine interfaces, human reactions and techniques for docking with a spacecraft having a definite relative velocity.

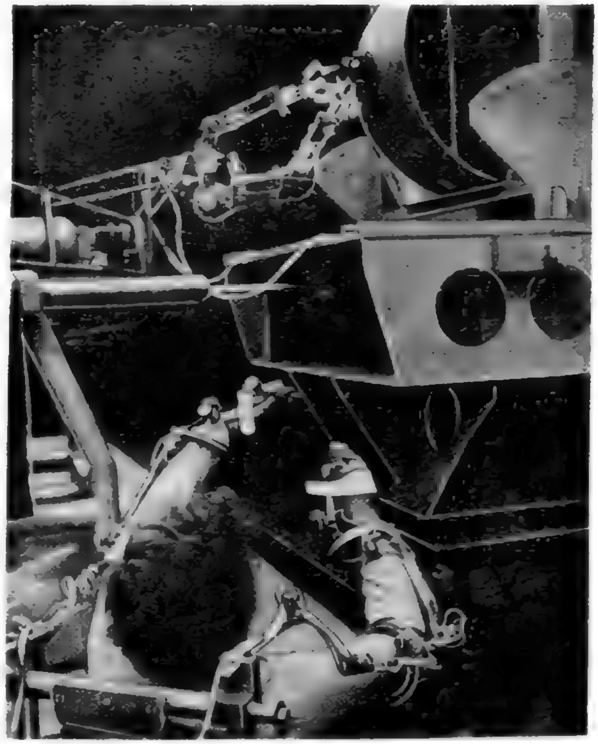
NASA turned to Bell Aerospace's Space Systems Department to conduct the appropriate analyses in its space simulation and test facilities. In this facility each attribute of the space environment needed to evaluate a teleoperator concept with the exception of vertical motions can be achieved on Earth with a five-degree-of-freedom teleoperator installed in a low-friction gimbal and extremely low friction air-bearing platform (for yaw, forward-reverse and lateral motions) with the one-g Earth field.

By reducing friction to extremely low levels, instability, control systems requirements, and docking difficulties associated with a flight teleoperator can be adequately simulated.

One of the more intriguing aspects of the first series of Space Shuttle missions will be the debut of the multi-purpose TRS. The TRS design concept evolved directly from supporting research and development that has been underway since the mid-1960's. The TRS was ordered by the NASA administrator in late October, 1977; the retrieval system's first assignment was to either re-boost the Skylab orbiting space laboratory to a higher orbit or to de-orbit it to a remote ocean area.

Instead solar activity was greater than expected, causing the atmosphere to expand. This in turn made more drag, speeding up Skylab's decay.

In November, 1977 a preliminary design contract was initiated with Martin Marietta, Corporation Division. The development schedule allowed for only two years and the low cost objective dictated maximum use of developed hardware. Most of the TRS components, with the exception of the TRS structure and the TRS support structure located in the Orbiter payload bay, consist of systems with components from other programmes, or are under contract and will be available, qualified and flown before the TRS is used.



Bell engineer tests the "master/slave" concept of extending man's ability to do work in space through teleoperators. Here, a thrust cluster is being removed from the side of a satellite mockup.

Bell Aerospace Company

The basic TRS core vehicle is box-like, 1.2 by 1.2 by 2.0 metres, with a triad of attitude control thrusters on each of its eight corners. The thrusters, having a nominal thrust of 7 lb (3.17 kg), will provide three-axis attitude control and backward and forward manoeuvrability.

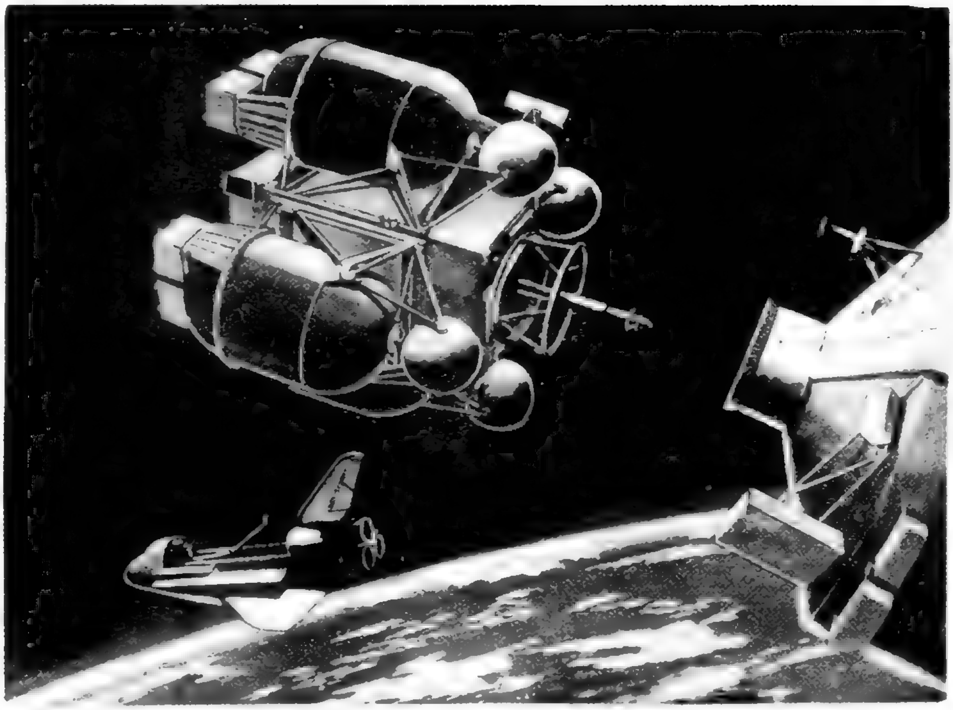
The core houses a guidance, navigation and control system, a communications and data management system and a propellant tank. A docking system is mounted on the forward end of the core, together with two TV cameras. On the core is a 24-nozzle hydrazine gas attitude control system that provides six degrees of freedom in controlling the vehicle during rendezvous, docking and initial orientation.

Guidance and control manoeuvres can be controlled either through pre-programmed instruction in the core computer, or through manual control by a Shuttle crew member, using support equipment in the Orbiter. Rendezvous manoeuvring and docking with the Skylab or any other objects in space would be accomplished remotely by the crew member, who can view the area to be docked with on a TV monitor located in the Orbiter aft flight deck.

The TRS has a central core with its own propulsion system. It is designed to accommodate strap-on kits which contain a propulsion fuel tank and pressurant supply and eight hydrazine rocket engines. The propulsion kits measure 1.4 metres in diameter and 1.5 metres long and carry 680 kg of hydrazine

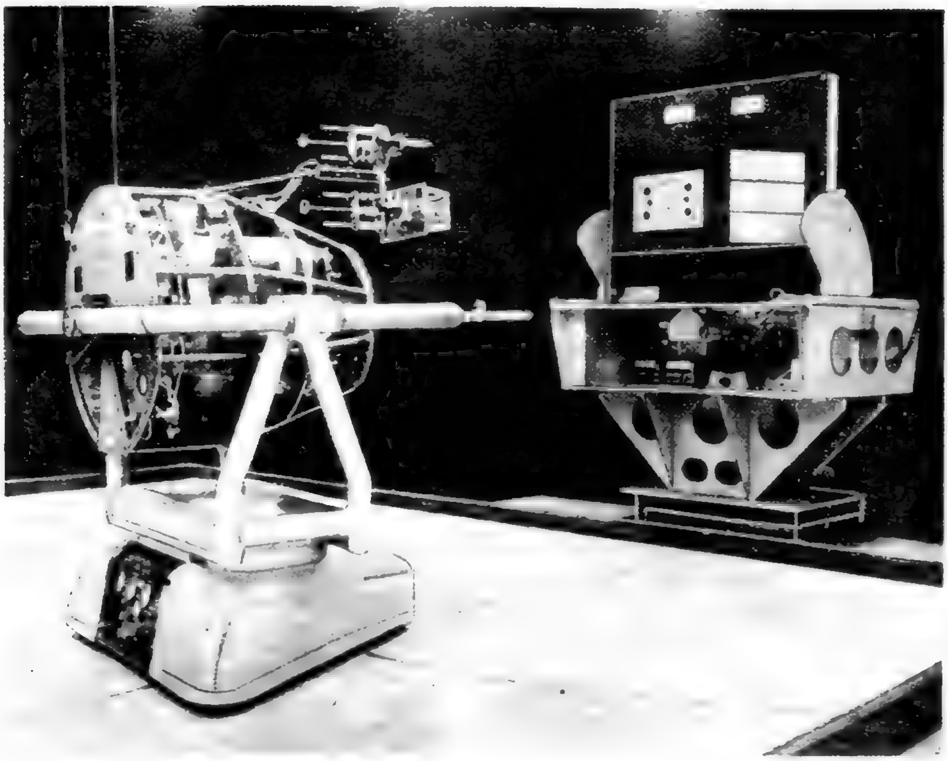
[Concluded on page 143

Artist's concept of a Teleoperator Retrieval System, to be used in conjunction with the Space Shuttle in the early 1980s, shows how it will approach a satellite for docking and retrieval. The low-thrust stage is retrievable and reusable and will be used to survey, stabilise and manoeuvre payloads in low Earth orbit. NASA's Marshall Space Flight Center, Huntsville, Alabama, is responsible for vehicle integration.



NASA

A Bell engineering model teleoperator heads toward laboratory workboard for simulated in-orbit satellite module exchange.



Bell Aerospace Company

LASING WITH LAGEOS

The National Aeronautics and Space Administration has selected 25 scientific investigators to use data obtained from its Laser Geodynamics Satellite (Lageos) with ground-based laser ranging systems.

These investigators will study the relative movement and deformation of the Earth's tectonic plates; variations in the motion of the Earth's polar axis and the Earth's rotation; solid Earth and ocean tides; the Earth's gravity field; and satellite orbital perturbations.

Seventeen of the principal investigators are affiliated with United States universities, private concerns or other government agencies. Seven are from other countries – France, West Germany, the United Kingdom and the Netherlands.

Lageos is part of NASA's Crustal Dynamics Project which is managed by its Goddard Space Flight Center (GSFC), Greenbelt, Maryland. Objective of the project is to improve understanding of the dynamic behaviour of the Earth which, in turn, should lead to a better understanding of earthquake mechanisms and crustal processes associated with the emplacement of mineral resources.

Lageos was launched on 4 May 1976 into a nearly circular orbit at an altitude of 5,800 km (3,600 miles) and an inclination of 110 deg to the Equator. The satellite is an aluminium sphere with a brass core. It is 60 cm (24 in) in diameter and weighs 411 kg (904 lb). The surface of the satellite is covered with 426 optical cube corners (reflectors) which retro-direct any incident optical signal.

The initial phase of the Lageos mission was devoted to determination of the precise satellite orbit and to development of the laser tracking systems. In the current phase, Lageos is being tracked by ground-based laser systems at several locations around the world.

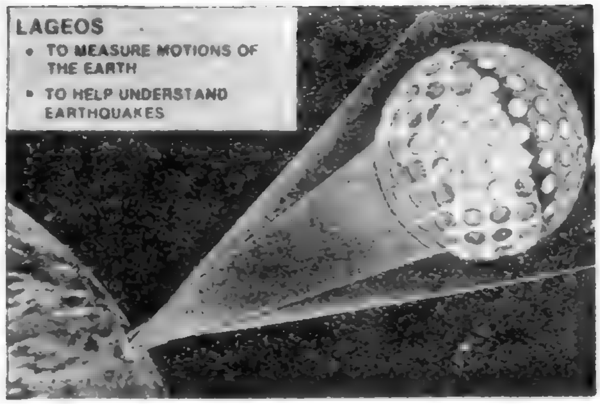
By accurately measuring the time for a laser pulse to travel to the satellite and return, the position of the laser system can be determined to about 10 cm (4 in). By repeatedly observing from several locations, the relative distance between laser locations and any change with time can be determined.

Lageos ranging data will be acquired with mobile laser systems on Kwajalein Island and American Samoa in the Pacific; in Western Australia; at Owens Valley and Goldstone, California; Ft. Davis, Texas; and the Haystack Observatory in Massachusetts. Fixed lasers at GSFC; at the McDonald Observatory in Texas; on Maui Island, Hawaii; at a US Air Force site in Florida and others operated by the Smithsonian Astrophysical Observatory in Natal, Brazil; Arequipa, Peru; and Orroral Valley, Australia, also will acquire data.

Lageos data also will be acquired by lasers in several countries in Europe. Data from a transportable laser ranging system, currently under development for NASA at the University of Texas, became available late last year. This highly mobile, truck-mounted, laser ranging system, designed to obtain precise Lageos ranging data, will support scientific investigations in the continental United States.

Several new space techniques provide unique capabilities for measurements of key geodynamics parameters. For example, crustal plate motion may be accurately measured by laser ranging to satellites, to retroreflectors on the Moon and by very long base-line microwave interferometry using extragalactic radio sources.

The high accuracy determination of the Earth's gravity field and geoid with laser tracking and altimetry from geodetic satellites provides information about the density distribution within the Earth which is essential in interpreting geophysical data relevant to geodynamics and resource location.



LASER TARGET. Lageos, launched in May 1976, has a diameter of 24 in (60 cm) and a mass of 904 lb (411 kg). Its "dimpled" appearance is the result of an array of 426 prisms that reflect laser beams. The retroreflectors are made of silica.

NASA

Prior to the launch of Lageos, satellite laser-ranging experiments were conducted by affixing laser retroreflectors to satellites performing a variety of missions. Lageos is the first NASA satellite designed solely for laser-ranging experiments.

The analysis and publication of the results portion of the investigations are generally planned for a period of three years and are to be completed by July 1982.

The selected investigations and investigators are as follows:

PLATE TECTONICS

Lageos Study of Polar Motion, Plate Rigidity and Plate Motions – W. Jason Morgan, Princeton University Princeton, N.J.

Precision and Reliability Station Determination in Selected Areas with a View of Investigating the Potentiality to Detect Relative Station Displacements – L. Aardoom, Delft University of Technology, Netherlands.

Measurement of Fault Motion in the Western United States – David E. Smith, Goddard Space Flight Center, Greenbelt, Md.

Determination of Worldwide Mobile Station Positions and Geodynamics Reference System – Peter L. Bender, National Bureau of Standards, Boulder, Colorado.

Earth Strain Measurements With the Transportable Laser Ranging System: Field Techniques and Planning – H. James Dorman, University of Texas, Galveston.

POLAR MOTION/EARTH ROTATION

Earth Rotation Parameters from Lageos and Lunar Laser Ranging (LLR) Data – Henry F. Fliegel, Jet Propulsion Laboratory, Pasadena, California.

Earth-Atmosphere Momentum Exchange and Lageos-Determined Rotation Rates – Richard D. Rosen, Environmental Research and Technology Inc., Concord, Mass.

Solid Earth Dynamics Using Lageos Range Observations – Byron D. Tapley, University of Texas, Austin.

Determination of Polar Motion and Earth Rotation from Lageos Data – Deiter Lelgemann, Satellitengeodasie der Technischen Universitat, Munchen, West Germany.

Comparative Studies of Polar Motion by Laser and Doppler Techniques – F. Nouel, Groupe de Recherches de Geodesie Spatiale, Toulouse, France.

Determination of Polar Motion and Earth Rotation from Lageos Data – David E. Smith, Goddard Space Flight Center, Greenbelt, Md.
Validation, Intercomparison, and Use of Laser Ranging and Radio Interferometric Data for the Determination of Geophysical Parameters – Irwin I. Shapiro, Massachusetts Institute of Technology, Boston.
Utilization of Range and Range Difference Observations in Geodynamics – Ivan I. Mueller, Ohio State University, Columbus.
A proposal for Comparison of Earth Rotation Parameters Derived by Satellite Laser Ranging and Radio Interferometric Techniques – D. McCarthy, US Naval Observatory, Washington, D.C.

EARTH ELASTICITY AND GRAVITY FIELDS
Use of Artificial Satellite Laser Data for Tidal Studies – A. Cazenave, Groupe de Recherches de Geodesie Spatiale, Toulouse, France.
The Value of Q at Tidal Frequencies Obtained From Laser Tracking of Lageos and Other Geodetic Satellites – Clyde C. Goad, National Oceanic and Atmospheric Administration, Rockville, Md.
Gravity Model Improvement Using Laser Data – W. T. Wells, EG&G/Washington Analytical Services.

ORBIT ANALYSIS
Analyze Satellite Tracking Laser Data in Order to Study Satellite Ephemerides, Solid-Earth and Ocean Tides and Laser System Performance – E. M. Gaposchkin, Smithsonian Astrophysical Observatory, Boston, Mass.
Investigation of Lageos Laser Data at the GRGS/Grasse – F. Barlier, Groupe de Recherches de Geodesie Spatiale, Grasse, France.
Development of a New British Orbital Analysis Programme – Arthur J. Meadows, University of Leicester, Leicester, United Kingdom.
Tentative Determination of General Relativity B Coefficient Using Secular Variations of Perigee of Laser Satellites – M. Lefebvre, Groupe de Recherches de Geodesie Spatiale, Toulouse.
Study of Relativistic Effects on Lageos Orbit Determination and Parameter Estimations – Chreston F. Martin, EG&G/Washington Analytical Services, Rockville, Md.
Studies of Atmospheric Refraction Effects on Laser Data – Peter J. Dunn, EG&E/Washington Analytical Services
Tracking Station Coordinate Determination and Lithospheric Plate Motion Investigation – Ronald G. Williamson, EG&G/Washington Analytical Services.

LIGHTNING AND NITROUS OXIDE

Lightning may be a source of two environmentally significant gases in the atmosphere according to laboratory tests conducted at NASA's Langley Research Center. The tests showed than an electrical discharge approximately equal to that of lightning can produce trace amounts of carbon monoxide and nitrous oxide.

Although the annual global rates of production due to lightning appear to be several orders of magnitude below that due to other sources, the level of nitrous oxide became twice as great and carbon monoxide was increased 100-fold in the vicinity of the laboratory lightning bolt.

Carbon monoxide initiates a complex series of chemical reactions that are believed to lead to the production of beneficial ozone in the lower atmosphere, or troposphere, at altitudes from 10 to 15 km (6 to 9 miles). Lightning adds to the already large man-made sources of carbon monoxide.

Nitrous oxide, ironically, is harmful because it leads to ozone destruction. It doesn't destroy ozone in the lower atmosphere, but rises and diffuses into the stratosphere, and is chemically transformed to a gas that depletes the Earth's protective ozone layer.

The highly-concentrated ozone layer, about 24 km (15 miles) above the surface of the Earth, absorbs much of the lethal solar ultraviolet radiation, thus shielding inhabitants of the Earth.

The major source of nitrous oxide in the lower atmosphere is thought to result from the action of microscopic bacteria on solid nitrogen compounds in the soil. This diffusion of nitrous oxide from the soil to the stratosphere takes about 25 years, so that it may be several decades before a measureable decrease in the ozone layer can be detected.

Nitrous oxide produced by lightning, however, may take only hours or days to reach the stratosphere, carried in the rapid updrafts of thunderstorms. Lightning flashes an estimated 500 times a second somewhere around the Earth. Tropical thunderstorms, especially, may be frequent conduits of nitrous oxide.

NASA researcher Dr. Joel S. Levine and his associates reported on the lightning studies, experimental results and theoretical calculations. Working with him were Langley's William E. Howell, Materials Division; the late Ron E. Hughes, Bionetics Corp., and Prof. William L. Chameides, University of Florida. Levine is in the Atmospheric Environmental Sciences Division of Langley.

Man's environmental responsibilities are not lessened by the finding of lightning-produced carbon monoxide and nitrous oxide, according to Levine, "because we know that man's activities are, in fact, altering the environment. Before we can assess man's impact fully, however, we must understand the natural processes, such as lightning, that alter the composition of the Earth's atmosphere."

Information obtained by the recent NASA Pioneer Venus space probe and USSR Venera missions suggests that lightning is a feature of the Venus atmosphere. The discovery led to the suggestion, based on theoretical calculations, that lightning may be a significant source of carbon monoxide in the Venerian atmosphere.

Levine and his Langley associates verified the theoretical calculations. Measurements made in the Lightning Facility and the Gas Analysis Laboratory, determined that carbon monoxide was increased dramatically in simulated Venerian atmospheric samples.

Recent photographs of the dark side of Jupiter, obtained by NASA's Voyager spacecraft, indicate that lightning also may be a feature of the Jovian atmosphere.

In early lightning studies, predating NASA, other researchers discovered that lightning may have been important in the biological processes that led to the origin of life on Earth, by converting nitrogen in the atmosphere from a gas to solid forms. They, in turn, were carried by rain into the oceans. One group of those solid forms of nitrogen would probably have been nitrates, essential building blocks in the origin of life. Lightning also may have supplied the energy that led to the formation of complex organic molecules, the precursors of life on Earth.

Lightning was known previously to be a source of nitric oxide, a compound important to the chemistry of the lower atmosphere. Nitric oxide molecules have a single nitrogen atom (NO); nitrous oxide has two N_2O). The production of gases by lightning results from the high temperatures which occur in the electrical discharge.

INTERNATIONAL OZONE PROJECT

Scientists and engineers from five countries – Australia, Canada, India, Japan and the United States – gathered at NASA's Wallops Flight Center on Virginia's eastern shore last October and November to compare their techniques of gathering information about ozone in the Earth's stratosphere. The programme included 20 rocket-borne experiments conducted

during a 14-day period to establish instrument precision and comparability.

Researchers pointed out that rocket-borne instruments in use worldwide employ different physical techniques to measure stratospheric ozone and had never before been compared to establish systematic errors and other biases in their measurements. A systematic comparison of all the instruments was necessary if rocket ozone data was to serve as "ground truth" verification of satellite measurements, particularly as the latter were coming to be relied upon to detect global ozone trends.

Four kinds of rockets—two-stage Nike Orion, single-stage Orion, Super Arcas and Super Loki – were used to carry the ozone measuring instruments into the stratosphere. The rocket flights were made to coincide with satellite overpasses of Wallops for comparison of the rocket measurements with those of the satellites. At the same time meteorological rockets and balloons, as well as ground based equipment, were collecting ozone data. New ground measuring techniques to determine the distribution of ozone in the stratosphere were also tested.

The joint effort was sponsored by the World Meteorological Organization, the Federal Aviation Administration of the Department of Transportation and NASA. Comparison of techniques is an important part of the world organization's Global Ozone Research and Monitoring Project since the use of satellite ozone measurements is placing increased importance on rocket data to verify, calibrate and determine long-term stability of satellite instruments.

Objectives of the rocket flights were to compare the performances of rocket-borne instruments under conditions that would:

- Establish the precision of various rocket ozone instruments;
- Assemble a common data base from rocket sounding, and
- Establish reference points for evaluation and use of future data by each experimenter.

By accomplishing the stated objectives, the project should help in providing additional data for:

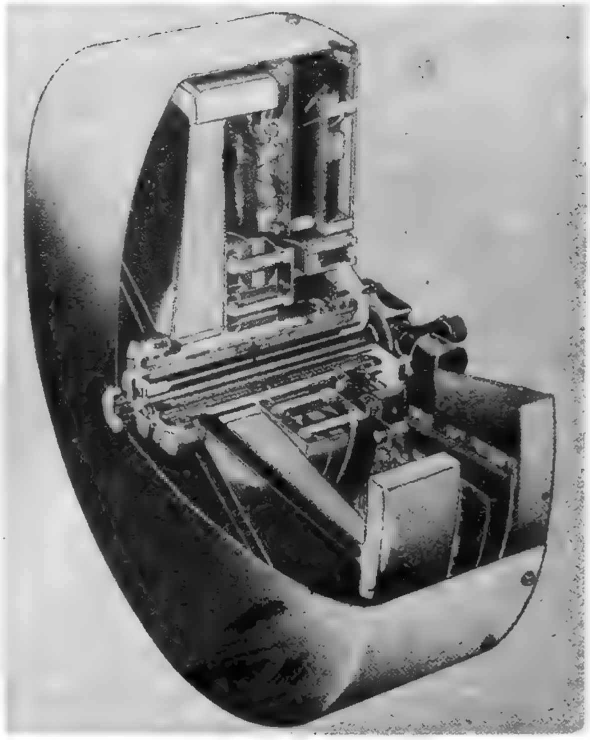
- Improving the accuracy of rocket ozone data used for validation of satellite ozone sensors;
- Establishing a selected set of upper level ozone profiles with greater accuracy, and
- Determining ozone trends, if any, at altitude levels where current stratospheric models predict the greatest reduction in ozone densities due to anthropogenic (man-made) pollutants, such as fluorocarbons.

MAGNETICALLY-SUSPENDED WHEEL

Trials of a magnetically-suspended momentum wheel of 50 Nms (newton metre second) capacity for satellite attitude control have been completed by the Stevenage Space Facility of British Aerospace Dynamics Group. The results are extremely encouraging and should attract the interest of satellite designers the world over.

Weighing 9.8 kg when complete with fully redundant control electronics and measuring 350 mm in diameter by 150 mm high, it is claimed to be the lightest wheel available in the world of this capacity. The company expects it to have a service-lifetime in space exceeding seven years.

Extended ground-running trials and qualification level testing have confirmed that the wheel meets its design requirements and conforms to the general flight requirements of space satellites. The wheel has been on loan to the European Space



The 50 Nms magnetically-suspended momentum wheel on which BAe Dynamics Group has completed engineering model proving trials. It is intended for satellite attitude control and stabilisation.

British Aerospace Dynamics Group

Agency (ESA) for evaluation.

The function of a momentum wheel in a satellite is twofold. First, by accelerating or decelerating the wheel, a reaction torque is imposed on the satellite body to control its attitude (or orientation). Second, by running the wheel continuously at a high nominal speed, the effect of the resulting gyroscopic stiffness is to stablise the satellite's attitude.

For long life satellites the prime requirements are low mass allied with high reliability and low power consumption. It is claimed that the BAe wheel meets these requirements. By incorporating magnetic suspension, the wheel rotor is not in contact with the stator and the mechanical wear and lubrication problems normally associated with rolling element bearings are completely avoided. Thus the company says, good reliability is ensured for high-speed operation over a long lifetime.

The magnetic bearing consists of a set of permanent magnet rings on the rotor with an inner, co-axial, matched set on the stator. Each ring is made of samarium cobalt (Sm-Co), the most powerful permanent magnet material currently available. The rings are axially magnetised, with adjacent rings positioned to provide a radial force of repulsion. This force provides radial stability of the suspended rotor. A servo-controlled electromagnetic actuator maintains the rotor in the correct axial position relative to the stator.

Two angular contact bearings provided at either end of the stator shaft act as emergency touchdown bearings. Sufficient clearance is provided so that in normal operation the rotating elements are not in contact. A launch-lock mechanism is provided to clamp the rotor onto the lower touchdown bearing with a force sufficient to prevent movement of the wheel during the satellite launching phase. After launching, the launch-lock mechanism is released pyrotechnically.

The wheel is driven by a three-phase 12-pole brushless dc motor with electromagnetic commutation. Should a temporary interruption occur in the satellite's electrical supply the motor,

acting as a generator, provides sufficient power to keep the electromagnetic axial actuator in operation. This is essential to sustain magnetic suspension. Less than 2.5 watts is needed to keep the wheel magnetically suspended. Total power consumption for a nominal speed of 6400rpm is 100 watts at full torque and 8 watts at zero torque.

The Stevenage Space Facility of British Aerospace Dynamics Group has been developing reaction and momentum wheels for the attitude control of space satellites since 1973. A 2Nms reaction wheel supported on angular contact bearings and operating at speeds of up to 2650rpm, by last October, had completed 10,000 hours (1.15 years) continuous running in a projected seven year life test. With the successful development of the 50Nms momentum wheel the Space Facility has the necessary design, manufacturing and operational experience to develop wheels of intermediate capacity with either magnetic suspension or rolling bearing support systems, as appropriate.

Reaction and momentum wheels energised by solar-generated power provide an effective low-cost low-weight solution to the attitude control of satellites where precise pointing accuracy and long life are necessary.

The Stevenage Space Facility of British Aerospace Dynamics Group is the only organisation in the UK to have established this particular engineering capability and proved the technology. The development of the momentum wheel was funded jointly by the Department of Industry, British Aerospace and the European Space Agency.

SCIENTISTS TRAP "COMET DUST"

Tiny particles of dust that may have been shed from a passing comet have been analyzed successfully by a group of university scientists working for NASA. Their results suggest that this unique, little-understood extraterrestrial material may contain chemical information dating back to the formation of the Solar System.

The successful analysis of single dust particles weighing only a thousand millionth of a gram was carried out by Dr. T. M. Esat, Dr. D. A. Papanastassiou and Prof. G. J. Wasserburg, all of the California Institute of Technology, and by Prof. Donald E. Brownlee of the University of Washington. The team used special instruments, originally developed to analyse Moon rocks and meteorites, that could handle, dissolve and analyze the tiny particles without loss or contamination.

"This is a real breakthrough", said Dr. Bevan M. French, discipline scientist for NASA's Planetary Materials Program, which supported the research. "There's a tremendous amount of this extraterrestrial dust around. About half a ton of it falls to Earth every day, and much of it may have come out of comets or new kinds of fragile meteorites that don't survive to reach the ground. We could get an enormous amount of new information; until now, we've never been able to collect these tiny particles free of contamination or to analyze them one at a time."

The successful analysis of possible "comet dust" comes at a time when NASA is actively planning a major mission to send an unmanned spacecraft to meet Halley's Comet when it returns in late 1985. The spacecraft would observe this major comet as it rounds the Sun and then would rendezvous with a lesser-known comet called Temple II.

But no samples can be returned from either comet by this mission, and the dust analyses are even more important for the near future.

Dr. Esat and his associates collected the dust particles by attaching sticky plates to a NASA-operated U-2 aircraft. Carried to an altitude of 20 km (65,000 ft), well above the contaminating terrestrial particles produced by volcanic eruptions and human activities, the plates trapped only extraterrestrial dust particles that had entered the Earth's atmosphere and were drifting downward.

Three different kinds of particles, most of them about 1/100th of a millimetre (1/2, 500th of an inch) across, were discovered when the plates were carefully cleaned at the University of Washington. The most common particles are fluffy, and each one is made up of as many as a million separate grains of different minerals. A second type is also fluffy, but is made up of many tiny crystals of a single mineral. The chemistry of these two groups, measured with a scanning electron microscope, is like that of chondrites, one type of meteorite that falls to Earth, but the fluffiness of the particles indicates that they were never a part of any dense meteorite. A rarer type of dust particle also was found – tiny hard spheres formed by a melting event that took place either in the Earth's atmosphere or in outer space.

For more precise measurements of the elements magnesium and calcium, the samples were transferred to Esat and his associates in a special laboratory at the California Institute of Technology.

This group hoped to detect small anomalies in the magnesium and calcium of the dust particles. Similar anomalies have been detected in the Allende meteorite that fell in Mexico in 1969. They apparently are caused by unique nuclear reactions that took place at the very beginning of the Solar System or even before – possibly in a nearby supernova explosion that may have triggered the formation of our Solar System.

Even for this experienced group, which pioneered the work on lunar samples, the analysis of a single dust particle demanded a new level of technical skill. All the work was done in clean rooms and under special hoods so that no terrestrial dust could contaminate the analysis. Each tiny particle was carefully moved with mechanical micro-manipulators until it could be inserted into a tiny drop of acid placed on a thin wire made of the high-temperature metal, rhenium. To make certain that the drop stuck to the wire, the scientists added a tiny bit of "orange juice" – a synthetic mixture of citric acid and sugar – to the drop. Then the wire was heated, the dust particle dissolved in the acid, the acid evaporated, and streams of atoms shot from the hot wire filament to be focused by a magnetic field and measured.

In most of the dust particles analyzed, the magnesium and calcium were "normal", i.e., like that found in Earth rocks and most meteorites. In four particles, possible anomalies were observed in the magnesium.

If these anomalies can be confirmed by analysing more dust particles, it will show that some of this dust came from objects that go back to the beginning of the Solar System – most likely comets, which have spent most of their time deep-frozen in the outer extremities of the Solar System since they were formed some 4,500 million years ago.

INMARSAT IN LONDON

The International Marine Satellite Organisation, INMARSAT, will eventually have a permanent headquarters in London, writes Geoffrey Lindop. INMARSAT will be a similar organisation to INTELSAT, but devoted to the telecommunications requirements of shipping. Currently 200 merchant ships have telecommunications links with the shore via MARISAT, which is primarily intended for use by the US Navy. It is estimated that by the mid-1980's over 2,000 ships of 20 nations will use the INMARSAT facilities.

INMARSAT will book some satellite time through the INTELSAT system, but most of the traffic will be routed through its own satellites which will be provided by ESA, namely MAROTS and MARECS, which are dedicated marine satellites of the same design as OTS and ECS. These satellites are being built by the MESH consortium comprising: British Aerospace Dynamics Group (prime contractor) United Kingdom; MATRA, France; SAAB-SCANIA, Sweden; ERNO, West Germany; AERITALIA, Italy; FOKKER-VFW, Netherlands, and INTA, Spain.

THE SOVIET SPACE FUTURE

At a Press conference given for the cosmonauts and astronauts at the IAF Congress on 17 September, a large body of correspondents expressed particular interest in Soviet plans for manned spaceflight following the successful Salyut 6 missions. The Soviet responses were translated by Prof. E. O. Fisher of the Technical University of Munich.

Cosmonauts attending the IAF Congress were Georgi Beregovoi, Alexandr Ivanchenkov, Anatoli Filipchenko, Vladimir Kovalyonok from the USSR and Sigmund Jaehn from the German Democratic Republic. Astronaut Alan Bean represented the United States.

One interesting new aspect was noted in several of the cosmonauts' answers to questions. This was a growing preoccupation with the cost side of space activities. This first came to light in the reply to the question whether the USSR is working on a transportation system comparable to the Space Shuttle. Such work, it was said, would be a normal extension of present systems, but the main problem was an economic one. Possible solutions were being studied that would not waste money. So far, summarized General Beregovoy, the money spent on space has brought in rich rewards and it will continue to do so in the future, but it must be used to solve Earth's problems.

No concrete joint US-USSR space project is being planned at the present time, said Alan Bean, but the astronauts would welcome one. The Russians were very pleasant to fly with, and theAmericans were looking forward to working with them again. General Beregovoy was also in favour of further joint projects, but added that basically an even wider international cooperation was needed. Earth resources missions were especially important, and all should unite their efforts to explore the Earth and solve the problems of life on Earth.

Unfortunately, no direct answer was forthcoming to the question of whether the USSR was interested in a solar power station such as was envisaged in the West. Instead, a long description was given of the need to improve the power supplies for satellites to enable still longer flights to be made.

Asked about what it was like to spend 140 days in space, the cosmonauts repeatedly stressed the need for constant physical exercise during the flight. The big problem is to ensure that man can not only live in space, but also work in a condition of weightlessness. The body must function in space as it would on Earth. A still better programme of physical exercises is needed in future. A new station is also in preparation that will be ready in about two years and provide much better living conditions for cosmonauts.

In reply to a question relating to the suggestion that had been made at the opening session that the IAF should be included in disarmament negotiations in view of the disquieting increase in military space activities, IAF President Roy Gibson said be felt the IAF should keep out of military space affairs. He did point out, however, that a lot of the work done by the military, for example on such equipment as sensors, was not of an aggressive nature. The military could get funding more easily and did a great deal that was also of use to civil programmes. International cooperation, of course, must keep away from any military interests.

Roy Gibson (BIS Fellow and IAF President) talking to Adrian Harbottle Reed (British Consul-General) during the IAF Congress in Munich.

SOCIETY MEETINGS. The variety and scope of meetings put on by the BIS in the second half of last year has brought much favourable comment. A highlight was the opportunity to meet Arthur C. Clarke, a former chairman of the Society whose contributions to astronautics – including the original concept of the communications satellite in geo-stationary orbit – have had the widest possible impact. In our picture (above) Arthur is seen meeting old friends and signing books at the special BIS meeting on 28 August. Other meetings attracting attention included the 3rd BIS Conference on Interstellar Studies on 11-12 September which resulted in more original contributions on this fascinating topic. The papers will appear in a forthcoming Interstellar Issue of JBIS. On 19 October a large number of members and guests enjoyed a relaxed evening with Members of Council and Staff of the Society at a Supper commemorating the 46th anniversary of the BIS, with entertainment provided by Mannock's Old Time Music Hall. Before the Supper, participants were able to view the new Headquarters Building in Vauxhall.

A. C. Clarke photo by Stephen Smyth

PROGRAMMING THE SHUTTLE TO FUTURE NEEDS

by David Baker

Introduction
In *Spaceflight* Vol 21, No 8-9 (the August-September, 1979, issue) a budget review of NASA funds sought to illuminate recent problems with Shuttle money. In that report I showed that R&D money actually spent in FY's 1976 to 1979 grew by 0.08%, 7%, 11.5% and 19.5% compared with sums estimated for each successive year. Since preparing that report the situation has changed and a further, supplementary, review of the current financial scene is relevant to consideration of future changes in NASA programmes. Table 1 shows the planned versus actual Shuttle R&D funding categories for 1976-1979 as outlined in the earlier review. What is now apparent is that NASA needed further sums for FY1979, the twelve-month period ending September 30, 1979, inflating the 19.5% increase in R&D costs to 28.2% by borrowing $70 million from the production fund.

From an original estimate of $857.2 million, Office of Space Transportation Systems spent an actual sum of $1,098.9 million during the financial year just ended. In my earlier report, FY1980 was said to need $511.3 million for Shuttle R&D. Based on worsening financial profiles, NASA has now revised this upward by $176 million, an increase of 34.4%. Table 2 shows the current estimates for a FY1980 supplemental of $220 million, the balance between this and the extra $176 million for R&D being accommodated by an additional $44 million requested for the Launch & Landing category.

Impact on Future Budgets
The history of percentage increases for FY1976 to FY1980 is now as follows: 0.08%; 7%; 11.5% 28.2%; 34.4%. It is unlikely that NASA will need to ask for more money in the FY1980 budget, although that period only began last October 1. What is uncertain, however is the impact on future budget years. Administrator Robert Frosch already believes the FY1981 and 1982 budgets will need between $200 million and $270 million per year extra, above the estimates already made for those two periods. Additional sums requested for FY1979 and FY1980 have clouded plans for early availability of the second Orbiter, called Challenger. Originally accommodating availability in February 1981, the FY1979 supplemental deferred Challenger by seven months. The FY1980 problem has now put Challenger back to March 1982 at the earliest. Third and fourth Orbiters – Discovery and Atlantis – are expected to be available in late 1983 and late 1984 respectively, more or less as planned.

Significant cost increases
Speaking earlier this year before the Senate subcommittee on Science, Technology and Space, Robert Frosch revealed that "Significant cost increases were disclosed by the Rockwell International Corporation, the Orbiter prime contractor, in October (1979), followed by similar increases for the other Space Shuttle elements . . ." Frosch said that NASA "intended to handle these identified increases within our planned reserves, and if the schedule had been maintained, the reserves probably would have been sufficient. However, it has become clear that additional funds must be expended in FY1979 for the Design, Development, Test and Evaluation (DDT&E) phase and additional DDT&E resources in FY1980 are also required."

Dr. Frosch itemised the prime offenders in delaying both mission operations and effective cost control:

(1) "A combination of technical problems and schedule extensions have caused substantial cost increase in subsystems such as the leading edge thermal protection system (LTV), the orbital manoeuvring engine (Aerojet) and the reaction control thrusters (Marquardt)."

(2) "The Orbiter KU band communications/rendezvous radar system implementation was previously delayed until flight STS-8 (author's note: the eighth manned flight). How-

Table 1: Shuttle funding profiles (planned versus actual) estimated January 1979*

	FY1976		FY1977		FY1978		FY1979		Totals
	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual	
Orbiter R&D	877.3	867.335	842.5	899.4	695.5	813.06	536.5	654.9	
SSME	135.5	140.8	193.8	182.2	219.9	197.4	176.7	161.4	
SRB	76.2	65.7	82.6	100.4	83.6	104.998	63.5	100.2	
ET	66.1	82.24	64.0	84.0	80.0	88.03	80.5	107.6	
Totals:	1151.1		1182.9		1079.0		8857.2		4274.2
		1156.075		1266.0		1203.488		1024.1	4649.663

*expressed in $×million.
Note: This profile represents R&D categories only, excluding L&L and Production; the FY1979 figure was an estimate in January 1979.

Table 2: Shuttle funding profiles (planned versus actual estimated June 1979*)

	FY1976-1977		FY1978		FY1979		FY1980	
	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual
Orbiter R&D	1719.8	1766.735	695.5	813.06	536.5	705.8	283.4	420.8
SSME	329.3	323.0	219.9	197.4	176.7	176.0	110.6	140.6
SRB	158.8	166.1	83.6	104.998	63.5	109.5	57.5	57.5
ET	130.1	166.24	80.0	88.03	80.5	107.6	59.8	68.4
Totals:	2338.0		1079.0		857.2		511.3	
		2442.075		1203.488		1098.9		687.3

* expressed in $×million
Note: This profile represents R&D categories only, excluding L&L and Production.

Table 3: Financial histories for Shuttle Funds by Fiscal Year*

	1978 Actual	1979 Plan	1979 Interim Estimate	1979 Final Estimate	1980 Plan	1980 Interim Estimate
DDT&E†	*1,307.500*	*985.300*	*1,170.300*	*1,250.300*	*610.500*	*830.500*
Orbiter	813.060	536.500	654.900	705.800	283.400	420.800
SSME	197.400	176.700	161.400	176.000	110.600	140.600
SRB	104.998	63.500	100.200	109.500	57.500	57.500
ET	88.030	80.500	107.600	107.600	59.800	68.400
L&L	104.012	128.100	146.200	151.400	99.200	143.200
Production	41.700	454.000	458.000	388.000	755.500	755.500
Orbiter	29.140	397.000	344.100	281.300	590.600	570.600
SSME	12.560	18.000	81.300	81.300	80.300	109.900
L&L	–	11.000	12.400	5.200	24.600	20.000
Spares	–	28.000	20.200	20.000	60.000	55.000
Total:	1,349.200	1,439.300	1,628.300	1,638.300	1,366.000	1,586.000

* expressed in \$×million. † subtotals

ever, the design and development effort for the KU band (Hughes) was substantially underestimated and additional effort is now required in FY1980."

(3) "The development of the S-band communications system (TRW) to be used for payloads has encountered a number of technical problems and is more complex than originally thought, thus requiring more effort.

(4) "A partial redesign is required on the auxiliary power units (Sundstrand) to institute an active cooling system to provide the capability for rapid restart of the system in flight."

(5) "The Honeywell flight control effort was substantially increased in FY1980 based on our experience in FY1979. Additionally, as a result of the experience in FY1979, and the schedule delay in STS-1, overall subcontractor support and analysis activities will be retained for a longer period of time and at a higher level than previously planned."

(6) "Additional Orbiter and systems integration engineering support (Rockwell International) throughout the flight test programme, and increased manufacturing personnel to complete mission kits (unique flight, test and/or support hardware) that were previously planned for FY1979."

(7) "The Orbiter qualification and certification test programmes have also experienced delays. Priority is being given to completing those tests designed to certify subsystems for the first test flight."

(8) "As a result of the main liquid oxygen valve failure in the main engine last December, it has been necessary to further delay the main propulsion system test. These tests, to verify propulsion system performance at main engine operation of 100% rated power level, will extend from FY1979 to FY1980 and additional tests have been added to certify the system at the 109% rated power level."

(9) "The astronaut suit, extravehicular mobility unit (EMU), and the portable oxygen system have experienced cost growth and schedule delays. The original Hamilton Standard contract estimates were optimistic and have been significantly affected by vendor cost escalation and delays."

(10) "The increased number of astronauts, requiring some small size units, has made it necessary to increase the number of sizes of EMU components and therefore increased our cost and schedule estimates. A recent EMU failure during astronaut training exercises in the watertank at JSC has further delayed this effort and added cost."

(11) "The external tank (ET) portion ... is principally attributable to unexpected cost increases in the manufacture and application of the thermal protection system (TPS) in FY1979, and the need to further improve the system. Manufacturing manpower greater than planned will be required through FY1980 for TPS application."

(12) "The Launch & Landing increase ... is necessary to sustain a larger workforce for launch operations than previously estimated. This requirement is based on our experience to date, which includes more development contractor personnel and overtime than previously projected."

(13) "Due to development motor manufacturing and subsystem qualification test problems, the Solid Rocket Booster manufacturing and assembly programme was impacted by increased manpower and overtime usage. The deliveries ... have slipped approximately two months."

As a result of cost increases and schedule slippage, NASA has received some of the harshest criticism ever levelled against it from Congressional committees. Congressman Larry Winn from Kansas told NASA's John Yardley that "I have a feeling that the Shuttle and the whole shuttle series is going to cost us a bundle more than we ever anticipated. Either our original estimates were bare-boned, just to get the programme going and our foot in the door, or else we have run into enough problems that it is going to cost the taxpayer a lot more money ... I am just wondering when we have a Proposition 13 affecting practically every bill that comes before the House – which you don't hear, and the chairman and I do – when you talk about 'it is going to cost just a few million more' here and there, that is what they are cutting out of every programme over there in the appropriations bill ... I don't know how many times we can go back to the well. I am trying to get that through to you."

Largely as a result of welcome management changes at a number of locations, all of which are reported in *Spaceflight*, the Shuttle is expected to fly the first development mission in the spring. Schedule boards set the flight for late March, but many expect that to realistically translate into a April-May flight period. But that date too would have been deferred had NASA chosen to develop an ability for thermal tile inspection on orbit. Tested beyond the maximum dynamic pressure anticipated for the first flight by tile samples applied to F-104 and F-15 aircraft, NASA plans to introduce an external inspection capability from the second flight. That will involve a Manned Manoeuvring Unit developed by Martin Marietta; plans for a television inspection by remote manipulator arm have been abandoned.

Effect on Future Programmes

In the four-year period 1979-1982, NASA will have spent an extra \$900 million on Shuttle development, a sum almost equal to that spent on the development of Project Viking. And it is the impact on future missions planning that concerns NASA the most in a climate of increased financial stringency from the White House. Moreover, any change in the leadership of a Democratic administration is likely to bring an even less acceptable attitude, for Edward Kennedy is a critic of America's space programme from the very days when John F. Kennedy set Apollo on a road to the Moon. But how do

SHUTTLE EMERGENCY DRILL. Navy divers on a two-year tour of duty at the Marshall Space Flight Center in Huntsville, Alabama, assist a space-suited subject in an underwater test of the procedure for solving a possible problem in space. In the event an airlock door cannot be closed during a future orbital mission, for example, the Shuttle astronauts will be able to make repairs. The procedure for jettisoning the door has already been worked out in this watery, simulated space environment on Earth.

NASA

inflated Shuttle needs impact pending programmes? Deeply.

Only a year ago NASA hoped to begin work on the VOIR – Venus Orbiter Imaging Radar – spacecraft. Designed to use Seasat technology for probing the opaque atmosphere of Venus to construct a topographic map of the planet, VOIR would have been launched by Shuttle in 1984 had the agency been allowed to request a funded start in FY1981. That period begins next October, and NASA has just completed talks with the Carter administration about projects for that period prior to public announcement of the total federal budget in January, 1980. It is unlikely that the agency will be allowed to make a start on VOIR, and because the launch opportunity for the favoured mission profile will not re-emerge until late in the decade, NASA will be unable to sustain momentum in the exploration of Earth's sister planet.

Moreover, because additional funds are required to support the Shuttle, over and above sums already budgeted in the five-year planning documents, it is unlikely that NASA will begin work on the Halley comet rendezvous project before FY1982. That is perilously close to the required launch date of mid-1985. Under plans now formulated, a single spacecraft will fly by solar electric propulsion to a close pass of the comet in December 1985, releasing a probe into its coma. Trajectory corrections will be made to steer the spacecraft on to rendezvous with Tempel II in December 1988, and to remain alongside this comet for six months before moving in for a landing.

The opportunity to achieve such a multitude of mission capabilities will require timely development of the Halley launch window, for if cometary exploration is left for later in the decade, funding costs will be the same while the richness of the mission will be severely depleted. But further than this, the funding supplement now thought necessary for Shuttle threatens to eject other planetary options from the decade's shopping list.

After VOIR, and the comet flight, NASA plans to ask for money in support of a Saturn-orbiter-dual-probe mission. This envisages a five-year flight to Saturn culminating in release of an entry probe prior to orbit insertion about the ringed planet. Later, a second probe would be released into Titan's atmosphere for the first scientific survey of this fascinating moon. The orbiter would continue to observe the Saturnian environment over an extended period. Just two years ago, prior to the request for additional Shuttle money, NASA's five-year planning schedule envisaged a funded start on the Saturn project in FY1983. One year later it was clear that the Saturn project could not receive funds as planned and the programme was put back to FY1985 at the earliest. Because the mission requires a four year development period and a five year trip time, it will not be possible to get orbiter or probes to their destination before 1994 – thirteen years after the last Voyager departs – at the earliest. And, it should be stressed, there is no guarantee of getting money for this in 1985.

Similarly ejected from the five-year shopping list is NASA's plan to explore Mars, a priority recommended by the Space Science Board of the National Academy of Sciences. In the August-September *Spaceflight* report it was said that funds would be requested in 1983 at the earliest for work on the sample-return programme. That date has now been put back to 1985 at the earliest which means that a precursor flight with geologic probes cannot now get to Mars before 1990, and that a sample-return vehicle would not reach the Red Planet before 1992; it would be 1995 before Mars material arrives on Earth. Again, this presupposes a funded start in 1985, the very earliest date NASA's optimistic shopping list will permit.

The Plight of Galileo

But future projects are not the only ones exposed to competing needs of the Shuttle development programme, for increased weight in the transporter hardware is forcing current projects to seek more money also. NASA's only planet mission currently approved but not yet launched is the Galileo flight originally planned for early 1982. That cannot now take place because the Shuttle is incapable of lifting spacecraft and booster to Earth orbit.

Utilising an Inertial Upper Stage, Galileo was expected to weigh approximately 2,060 kg of which 1,700 kg would be taken up by the orbiter bus and 245 kg by the probe; the balance would be absorbed by the IUS adaptor and a mission reserve of 15 kg. About half the bus weight was to be taken up with propellant to brake the vehicle into Jovian orbit, so little remained for a weight reduction effort (a large saving in vehicle mass would bring about a smaller reduction in propellant mass). To inject a mass of 2 tonnes on to a trans-Jovian

trajectory would have required a three-stage IUS weighing about 25 tonnes. Accordingly, the total payload mass to Earth orbit would have been about 27 tonnes. Well within the advertised Shuttle lifting capacity of at least 29 tonnes.

However, it has become clear in recent months that serious weight growth in the Shuttle, plus an initially conservative engine performance, provides the Orbiter with a serious payload deficit. When Columbia flies it will be limited to payloads totalling no more than 17 tonnes. By early 1981 it is hoped that tests with main engines will have increased this to about 19.5 tonnes by allowing a thrust level of 109% to be applied after liftoff. About six months later, it is hoped that still more testing will permit 109% throttle settings before liftoff, raising payload capacity to about 23 tonnes. But this is still far short of the 27 tonnes needed to get Galileo spaceborne. Up to mid-1979 NASA counted on availability of the second operational Orbiter ("Challenger"), which was to have been ready by 1981, to bridge the capability gap: weight reduction in Challenger should give this vehicle a payload capability of 27 tonnes. But now, because NASA borrowed from production money to settle development bills, Challenger will not be available before spring 1982. Galileo's launch window ends in February of that year. And the alignment of the planets prevents even the full capability IUS/Shuttle configuration from flying a Galileo type vehicle again before the mid-1990s. Once missed in early 1982 the window is closed for more than a decade.

So where does that leave Galileo? Options centre on two configurations: separate orbiter probe vehicles launched in 1984 on two Shuttle flights; or development of the cryogenic Centaur stage for this and other planetary objectives. If launched as two flights, re-development costs plus launch fees for a second mission could cripple the attempt. In any event that would call for a postponement until 1984 at the earliest; NASA has an international solar-polar project for launch in 1983 which would require two separate missions and three space vehicles to fly to the same planet simultaneously, and in any event the weight improvements are not expected before 1984.

As an alternative, the orbiter could fly in 1984 followed by the probe vehicle in 1988, an optimum mission sequence as far as costing goes and one favoured by some Congressional supporters. The less probable alternative would give planetary mission planners availability of the Centaur liquid propellant stage, a booster many wanted from the beginning when transportation needs centred on a solid propellant commonality for all Shuttle boost units. And it would give a payload increase over the solid IUS. But development for Shuttle use, plus modifications to adapt the Orbiter for cryogenic handling, could top $200 million, rendering this an unlikely option. If adopted, however, the complete orbiter/probe Galileo originally planned for a 1982 flight could get away in 1987 after minimum-cost development time.

Inevitably, any delay in getting Galileo operational will have serious repurcussions on the health of programme offices at CalTech's Jet Propulsion Laboratory. Already, with little probability of getting VOIR in the forseeable future, managers are worried about the momentum falling off where success and proficiency depend to a large extent on pace and "negative-slack" in the schedules. As it stands, after two Saturn encounters the only programmes currently approved foresee a possible inspection of Uranus in 1986 and an orbiter for Jupiter toward the end of the decade.

But if planetary programmes can be juggled for appropriate launch capabilities, military missions for the mid-1980s are not so flexible and NASA is obliged to provide the Defence Department with a so-called Mission 4 capability by June, 1984. Mission 4 stipulates a 14.5 tonne payload delivered to a circular 278 km orbit inclined 98°, provision of an on-orbit ΔV of 320 metres/sec, and retrieval and return of a 11.3 tonne payload from that orbit. It is a requirement stimulated by the Big Bird successor now in development and one that is equivalent to a 29.5 tonnes load placed in a low due east orbit from the Kennedy Space Center.

To accommodate this requirement an extensive weight saving programme envisages up to 2,270 kg removed from the dry Orbiter mass, up to 2,720 kg removed from the ET, 317 kg taken from each SRB and 91 kg saved from each main Orbiter engine. Maximum weight savings would be applied to the third and fourth operational Orbiters – Discovery and Atlantis – with lightweight tank and boosters available for Columbia and Challenger some time in 1982. However, gross payload capability will increase by 900 kg for second and third Orbiters, respectively. Savings in the External Tank will stem from a reduced safety factor of 1.25 from a current 1.4 times design load. Stringers, slosh baffles, aft dome caps, intertank, and thermal protection areas can be significantly thinned out by relaxing constraints. Electrical cables can also be transferred to the interior for additional weight savings. SRB savings will be limited to reduced case thickness.

With these improvements, payload to due east orbit is expected to be 27 tonnes by 1982. Mission 4 requirements were to have been met by the third Orbiter but Discovery will now have only a 28.2 tonne due east capacity even with lightweight tanks and SRBs; the additional 1.2 tonnes comes from improvements in Orbiter fabrication compared with the previous vehicle (Challenger). It is necessary, therefore, to employ a supplementary propulsion system to improve the Shuttle's carrying capacity to the level where it can match the Mission 4 requirement. This comes in the form of Strap On Solid Motor (SOSM) assemblies, one attached to each SRB, raising due east capacity to approximately 32.2 tonnes for a 98° potential of the required 14.5 tonnes. NASA hopes to begin development by mid-1981 so that SOSM configurations are ready by mid-1984. If additional strap-ons were clustered beneath the External Tank, payload capacity would increase to 28.5 tonnes and 20.4 tonnes for due east and 98° orbits, respectively.

But that is a future option without consideration for hardware development at present. As it stands, Shuttle operations will be limited to (due east) payloads of 17 tonnes until early 1981, when it will grow to 19.5 tonnes, increasing to 23 tonnes later the same year. By 1982, capacity should be 27 tonnes and in 1983 that should increase to 28.2 tonnes when Discovery becomes available. Capacity would be 32.2 tonnes by 1984 if SOSM developments evolve as planned. Although deficient in early years, the original requirement for a 29.4 tonne payload should be met and significantly improved by implementing modest development efforts.

But the inevitable impact of inflated financial requirements will stifle many programmes NASA had hoped to begin during the 1980s. Planetary science commands only 4% of the total NASA budget, representing the only effort now applied to investigating the physics and evolution of the Solar System. If further cuts are not to irrevocably damage the institutional base built up through nearly two decades of active lunar and planetary science, political ignorance about the cultural needs of nation-states must be allayed.

There are already sombre signs of decreasing awareness about the value such programmes bring and in the absence today of a space programme tuned to prestigious nationalism, other less beneficial forces are marshalled for political gain. In the two years between FY1978 and FY1980, Defence Department spending on military space programmes increased by a phenomenal 60%; were it not for the Shuttle supplemental requested for the current year, NASA's space budget authority would already be less than that of the Defence Department's space effort. Next year it will be greater than NASA's budget. Unless determined action is taken now to reverse the trend, many civilian programmes with little or no financial benefit will probably be lost.

[Concluded on page 143

SATELLITE DIGEST-135

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. A detailed explanation of the information presented can be found in the January, 1979 issue, p. 41.

Continued from February issue

Name, designation and object number	Launch date, lifetime and descent date	Shape and weight (kg	Size (m)	Perigee height (km)	Apogee height (km)	Orbital incli- nation (deg)	Nodal period (min)	Launch site, launch vehicle and payload/launch origin
Molniya-1(45) 1979-91A 11589	1979 Oct 20.29 12 years	Cylinder-cone +6 panels +2 antennae 1000?	4.2 long 1.6 dia	618 615	40624 39740	62.82 62.86	735.83 717.76	Plesetsk A-2-e USSR/USSR (1)
Cosmos 1142 1979-92A 11592	1979 Oct 22.52 13 days (R) 1979 Nov 4	Cylinder +sphere + cylinder-cone? 6000?	6 long? 2.4 dia?	197 352	381 417	72.87 72.86	90.33 92.38	Plesetsk A-2 USSR/USSR (2)
Cosmos 1143 1979-93A 11600	1979 Oct 26.76 60 years	Cylinder +2 panels? 2500?	5 long? 1.5 dia?	622	645	81.25	97.44	Plesetsk A-1 USSR/USSR (3)
Magsat 1979-94A 11604	1979 Oct 30.59 6 months	Octagonal prism +4 panels +boom 181	1.64 long 0.77 dia	354	561	96.80	93.80	WTR Scout G NASA/NASA (4)
Meteor 2 (5) 1979-95A 11605	1979 Oct 31.40 500 years	Cylinder +2 panels +2antennae 2750?	5 long? 1.5 dia?	872	889	81.21	102.63	Plesetsk A-1 USSR/USSR (5)
Intercosmos 20 1979-96A 11609	1979 Nov 1.33 18 months	Octagonal ellipsoid? 550?	2 long? 1.5 dia?	465	510	74.03	94.40	Plesetsk C-1 USSR/USSR (6)
Cosmos 1144 1979-97A 11611	1979 Nov 2.67	Cylinder +sphere + cylinder-cone? 6000?	6 long? 2.4 dia?	167	357	67.15	89.78	Plesetsk A-2 USSR/USSR (7)

Supplementary notes:

(1) USSR domestic communications satellite. Orbital data are at 1979 Oct 23.4 and Nov 3.4
(2) Orbital data are at 1979 Oct 22.5 and Oct 23.7.
(3) Military satellite, possibly an electronic ferret.
(4) NASA scientific satellite, designed to measure the near-Earth magnetic field and crustal anomalies. The satellite is intended to operate for a minimum of 4 months, but natural decay will occur after six. The spacecraft flight hardware was left over from the Small Astronomical Satellite (1975-37A).
(5) Fifth of the USSR's second generation meteorological satellites, returning cloud cover photographs and meteorological measurements.
** (6) Eastern bloc co-operative launch of a scientific satellite.
(7) Manoeuvrable reconnaissance satellite.

Amendments:

1965-39A, Pegasus 2 decayed 1979 Nov 3, lifetime 5275 days.
1979-83A, Cosmos 1129 was recovered 1979 Oct 14 after 18 days.

[*Continued on page 142*

MILESTONES/*continued from page 97*

19 Soyuz-T spacecraft docks with Salyut 6 under automatic control.

23 Second attempt to launch Ariane L01 at Kourou, French Guiana, is frustrated by minor technical hitches and adverse weather conditions.

24 ESA launches Ariane L01 rocket from Kourou, French Guiana, at 17 hours 14 minutes and 38 seconds GMT to: 1. Verify the functioning in actual flight of devices which had been tested as thoroughly as possible on the ground. 2. Obtain data on elements which cannot be simulated on the ground. 3. Verify the performance of the launcher and its subsystems. Object was to place a CAT (Capsule Ariane Technologique) into an orbit ranging between 200 and 35 753 km inclined at 17.5 deg to the equator to obtain data on the rocket's performance. ESA described the launch as a total success with all stages of Ariane firing on schedule and the payload separating at the planned time. Next test launch of a CAT plus Firewheel (Max Planck Institute, study of magnetosphere) and Oscar 9 (AMSAT, radio amateurs) is scheduled in May 1980; intended orbit is again geostationary transfer.

INTO SPACE FOR NEW MATERIALS

By Sergei Grishin* and Leonid Leskov†

Introduction

It is some time now since cosmonauts Vladimir Lyakhov and Valery Ryumin worked aboard the orbital station Salyut 6. Technological experiments connected with obtaining new materials under micro-gravity conditions occupied an important part of their investigations. To carry out such experiments special installations 'Splav' and 'Kristall' were developed, incorporating ampoule electric heating furnaces and power supply and control panels.

Preliminary examination of the samples of semi-conducting metal and optical materials brought back from Salyut 6 in 1978 had already suggested that they were better than those made in laboratories on Earth. Examples were obtained of composite materials and of alloys which are difficult to synthesise on the Earth because of greatly dissimilar densities of the components. The monocrystals of germanium and indium antimonide, grown in outer space, possess much better strength properties, and the impurities are more evenly spread in them.

Two prolonged expeditions to the Salyut 6 station have carried out some 90 technological experiments, each of which required thorough preparation. The duration of individual experiments exceeded several dozen hours. The study of samples brought back from space involves the use of unique equipment and also takes up much time.

All this indicates the importance of careful ground preparation of technological experiments. Some of the expected effects can, however, be checked in conditions of short weightlessness, during, for example, the launching of high altitude rockets.

Research with Sounding Rockets

The first technological experiments on high altitude rockets of the Mir-2 complex were carried out in the USSR in March 1976. The duration of micro-gravity reached 10 minutes. That was enough to check the apparatus and to conduct experiments on alloy solidification and the production of some composite materials. For example, the mock-up of the Reaktsia instrument, by means of which experiments in metal soldering in micro-gravity conditions were made aboard Salyut 5, was initially tried out during a high altitude rocket launch.

In 1978, a high altitude rocket for the first time tested a special accelerometer by means of which direct measurements were made of the magnitude of small accelerations acting on the spacecraft. It is essential to know the magnitude of these modest forces when carrying out technological experiments.

Exothermic Chemical Reactions

To smelt materials during short-term micro-gravity a special complex of automatic instruments, SKAT, was developed. They make use of the heat of exothermic chemical reactions, while the rapid cooling of the samples to the temperature of hardening relied on a special system of thermal sink.

The thermal capacity developed by one instrument reaches 70 kilowatts, and maximum temperature 1700 degrees Centigrade. Such high capacities have made it possible to use the SKAT complex for experiments on diverse substances: composite materials, foamed metals, special alloys, and semi-conductors. To increase the accuracy of results nearly all experiments were replicated.

In 1976-1978 in the Soviet Union, some 70 technological experiments were conducted when launching high altitude rockets. In particular, scientists obtained samples of composite materials (for example, aluminium reinforced with carbon fibres) which possessed the high distribution uniformity of components in the mass.

Similar properties are shown by samples of foamed metals made with the help of the SKAT apparatus. All these experiments, as well as Salyut 6 experiments, confirm the possibility of controlling the structure of materials in space conditions with a view to improving them.

Splav and Kristall

Electric heating installations Splav and Kristall, like similar apparatus developed abroad, are designed for smelting samples at a temperature of not more than 1,000-1,200 degrees Centigrade. So it is as yet impossible on these installations to conduct experiments in directional crystallisation of materials whose melting point is over the limit. Such materials include, for example, silicon – the basic material of the present-day electronics industry.

The monocrystal slabs of silicon were first obtained through directional crystallisation by means of the SKAT equipment in conditions of short-term weightlessness. Samples of silicon grown on the Earth with the help of the same apparatus possess a polycrystal structure.

It is also possible to obtain another major semi-conducting material – monocrystal germanium. Experiments on high-altitude rockets made it possible to get additional information on the specific features attending the consolidation in weightlessness. It was established, in particular, that it is possible greatly to speed up the rate of crystallisation in the germanium melt. Monocrystalline slabs of germanium were obtained whose quality was not worse than in the seed crystal, while the rate of growth attained 100 microns a second. At the same time the control samples of germanium obtained by the same apparatus on the Earth had a polycrystalline structure.

Behaviour of Liquids

Investigations of the behaviour of liquids were started in 1976 when Salyut 5 was in flight. During launchings of high altitude rockets of the Mir-2 complex slabs of copper and silver were obtained which freely consolidated under micro-gravity conditions. As an analysis of the samples brought back from outer space has shown, non-sphericity amounted to about one per cent. These results are important in perfecting installations for the containerless production of materials in outer space.

An experiment was staged to determine the possibility of growing profiled crystals on board the spacecraft. Such monocrystals are used extensively in the electronics industry.

Yet other promising trends in space technology are connected with the manufacture in micro-g conditions of particularly pure medical and biological preparations – vaccines, enzymes and antibiotics. In doing so it is necessary to solve the complex technical problem associated with the preservation of the biological activity of these preparations over long periods. It is thought that this problem, too, will find its solution.

Space technology has a big future.

*Doctor of Technology; †Doctor of Physics and Mathematics.

SATELLITE DIGEST – 135/*continued from page 141*

General note:

Recent compilations of SATELLITE DIGEST have been affected by problems in the distribution of orbital information from the Goddard Space Flight Centre. Missing items, such as catalogue numbers and certain orbital data will be included as amendments as soon as they become available.

CORRESPONDENCE

Out of this World!

Sir, I attended the 3rd BIS, Conference on Interstellar Studies and I must say that never before have I had a more enjoyable, or wholly well spent time in my life. The topics discussed were excellently covered by the speakers and there was ample time left for the audience to question them on their papers. Some of the the topics were of great personal interest, i.e., "In-flight Maintenance of Starships" (T. J. Grant), "The likelihood of Finding Extraterrestrial Laser Signals" (Monte Ross), and "Propulsion Requirements for a Quantum Interstellar Ramjet" (H. D. Froning, Jr). Others were new to me like E. J. Coffey's "The Nature of Living Organisms", and "The Improbability of Intelligent Extraterrestrials" (A. Bond) which have given me much food for thought. This was the first such conference of the BIS I have been able to attend, and I would like to thank all those who had a part in making it possible.

G. WARDLE
Gosport.
Hampshire.

Histories and Launch Logs

Sir, I note that Anthony Kenden in the July 1978 issue of *Spaceflight* lists a Titan 3B/Agena D launch failure on 5 June 1974, one day before the successful launch of 1974-42A. I have seen this launch failure listed in *TRW Space Log*, but not anywhere else and I would have thought that it must be a mistaken reporting of the successful launch the following day, since there is only one Titan 3B launch pad – SLC 4a. Otherwise, the new launch vehicle would have had to be set up on the pad from scratch in one day, which seems unlikely.

Finally, may I say that I think the articles by Andrew Wilson giving histories and launch logs of various rockets are a very good idea and a useful reference. I think it would be a good idea to eventually print entire launch histories* of the Atlas and Thor vehicles.

JONATHAN C. McDOWELL,
Churchill College,
Cambridge.

* *Mr. McDowell will be pleased to learn that this task is already under way. Ed.*

PROGRAMMING THE SHUTTLE TO FUTURE NEEDS
Concluded from page 140

After this article was written NASA decided to request an additional $300 million for the current FY1980 period in addition to the supplemental approved earlier last year for Shuttle R&D. This means a 93 per cent increase over the original plan rather than the 34.4 per cent described in the article. Also, the Office of Management and Budget has rejected the request for support of the Halley/Tempel 2 mission as part of the FY1981 budget. Ed.

THE BIRTH OF THE MECHANICAL SPACEMAN
Concluded from page 130

and each of its eight rocket engines has a minimum of 164.65 newtons of thrust.

The TRS communications and data management hardware in the Orbiter are located on the aft flight deck. Special hand controls, a TV monitor and other controls and displays, are required so that a crew member can remotely control or monitor the teleoperator through all phases of the mission.

The command station aboard the Orbiter will be used for transmitting commands to the TRS, receiving and processing telemetry from the TRS and to receive TV pictures from the TRS.

Since the abandonment of the Skylab revisit mission the overall TRS Programme plans and the basic TRS configuration have been re-evaluated. Over the next two years the actual configuration performance capabilities will be further evaluated. The hope of the space agency is to make TRS available for payload placement and retrieval missions by 1984.

ALLAN D. EMIL MEMORIAL AWARD

The I.A.F. has notified all Member Societies that an ALLAN D. EMIL MEMORIAL AWARD for international cooperation in astronautics has been established. Procedures and guidelines are as follows:

A. *Proposal of candidates:*

1. An international Emil Award Committee will be designated each year by the I.A.F. Bureau to examine nominations.
2. The member societies will be invited to submit names of candidates, accompanied by an appropriate documentation, to the I.A.F. Secretariat within the three months following the annual Congress, for transmittal to the Committee.
3. The Committee will consider nominations and submit a motivated and documented recommendation to the I.A.F. Bureau, one month before the Spring Session of the Bureau.

   The final decision will rest with the Bureau and will be taken during its Spring Session. The recipient will be notified of the award by the I.A.F. President, and must have accepted the award before it is made public.

B. *Criteria*

The award will be presented annually for an outstanding contribution in space science, space technology, space medicine, or space law which involved the participation of more than one nation and/or which furthered the possibility of greater international cooperation in astronautics.

C. *Format and content*

1. The award will consist of a stipend of $1,000 offered by the family of Allan D. Emil and a certificate furnished by the I.A.F.
2. The text of the certificate will be in English; it will have a standard form and a citation applicable to the specific recipient.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 27/29 South Lambeth Road, London SW8 1SZ

Correspondence and manuscripts intended for publication should be addressed to the Editor, 27/29 South Lambeth Road, London SW8 1SZ.

Lecture
Title: **THE NEW FACE OF THE UNIVERSE**
by A. T. Lawton

A summary of the lectures in the Space Study series entitled "The Origin and Evolution of the Universe" to be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ on **12 March 1980.** 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Lecture
Title: **THE DEVELOPMENT OF THE BLUE STREAK ROCKET**
by C. H. Martin

To be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ on **9 April 1980,** 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Lecture
Title: **JUSTIFICATION OF SPACE PROJECT PROPOSALS**
by E. G. D. Andrews

To be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ on **23 April 1980.** 7-9 p.m.

"In the design of proposals for a major project, especially one contemplating space or interplanetary colonization, it may be necessary to take into account a wider range of constraints than can be properly organized by any single human mind unaided. The speaker has introduced a formal procedure (PADIS) based on the logic of the natural design process, which identifies the sequence in which the design investigations should be carried out to minimize reiteration, and permit effective collaboration in design to be provided by all who have relevant knowledge, without interfering with the conceptual tasks. The design of a lunar village is used for the purposes of illustration".

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Lecture
Title: **PLANET VENUS: 1980**
by John Bury

A lecture with a short discussion on recent experimental results and their interpretation with regard to the planet Venus, to be held in the Golovine Conference Room, Society's HQ, 27/29 South Lambeth Road, London SW8 1SZ, on **14 May 1980,** 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

17th European Space Symposium
Theme: **ASTRONAUTICS IN THE 1980s AND BEYOND**

A three-day meeting to be held at the Royal Commonwealth Society, London W.C.2 from 4-6 June 1980, sponsored by the BIS, AAAS, AIDAA and DGLR and co-sponsored by EUROSPACE.
Offers of papers are invited. Please contact the Executive Secretary for further information. Registration is necessary. Copies of the programme will be available in due course.

SOLAR ECLIPSE JULY 31ST 1981

The Southern California Branch is interested in making up a small group expedition to view the solar eclipse on 31 July 1981. A tour of about three weeks in duration is envisaged, flying from Los Angeles with connections from the United Kingdom, and continuing via Ulan Bator, Ulan Uda to the vicinity of Novosibirsk for the viewing, thence with return to Warsaw via Soviet Georgia, for the flight back to the UK/USA.
Arrangements will be in the hands of Mr. R. V. Frampton, Mail Stop 264-519, Jet Propulsion Laboratory, Pasadena, California 91103, USA. Members interested should contact Mr. Frampton for inclusion in the preliminary list of participants.
The total cost will be dependent upon the number participating.

Visit
SRC APPLETON LABORATORY

Arrangements have been made for a small party of members to visit the SRC Appleton Laboratory at Ditton Park, Slough, together with a visit to their out-station, the Satellite Signal Reception Centre at Winkfield, on **10 September 1980** (all day).

Registration is necessary. Members interested in receiving further information must apply to the Executive Secretary, enclosing a reply-paid envelope, in good time.

35th ANNUAL GENERAL MEETING

The 35th Annual General Meeting of the Society will be held in the Tudor Room, Caxton Hall; Caxton Street, London S.W.1 on **18 September 1980,** 7.00 p.m.

A detailed Agenda will appear in *Spaceflight* in due course.

Nominations are invited for election to the Council. Forms can be obtained from the Executive Secretary. These should be completed and returned not later than 25 June 1980.

Should the number of Nominations exceed the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members.

31st IAF CONGRESS

The 31st Congress of the International Astronautical Federation will be held in the Takanawa Prince Hotel, Takanawa, Minato-ku, Tokyo, Japan from **21–28 September 1980.**

Members of the Society intending to present papers are asked to notify Dr. L. R. Shepherd, Chairman of the BIS International Liaison Committee at Society H.Q. as soon as practicable.

Lecture
Title: **SPACE REVIEW – 1980**
by P. S. Clark

A review of space activities throughout the world which have taken place during the past twelve months, to be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ, on **8 October 1980,** 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

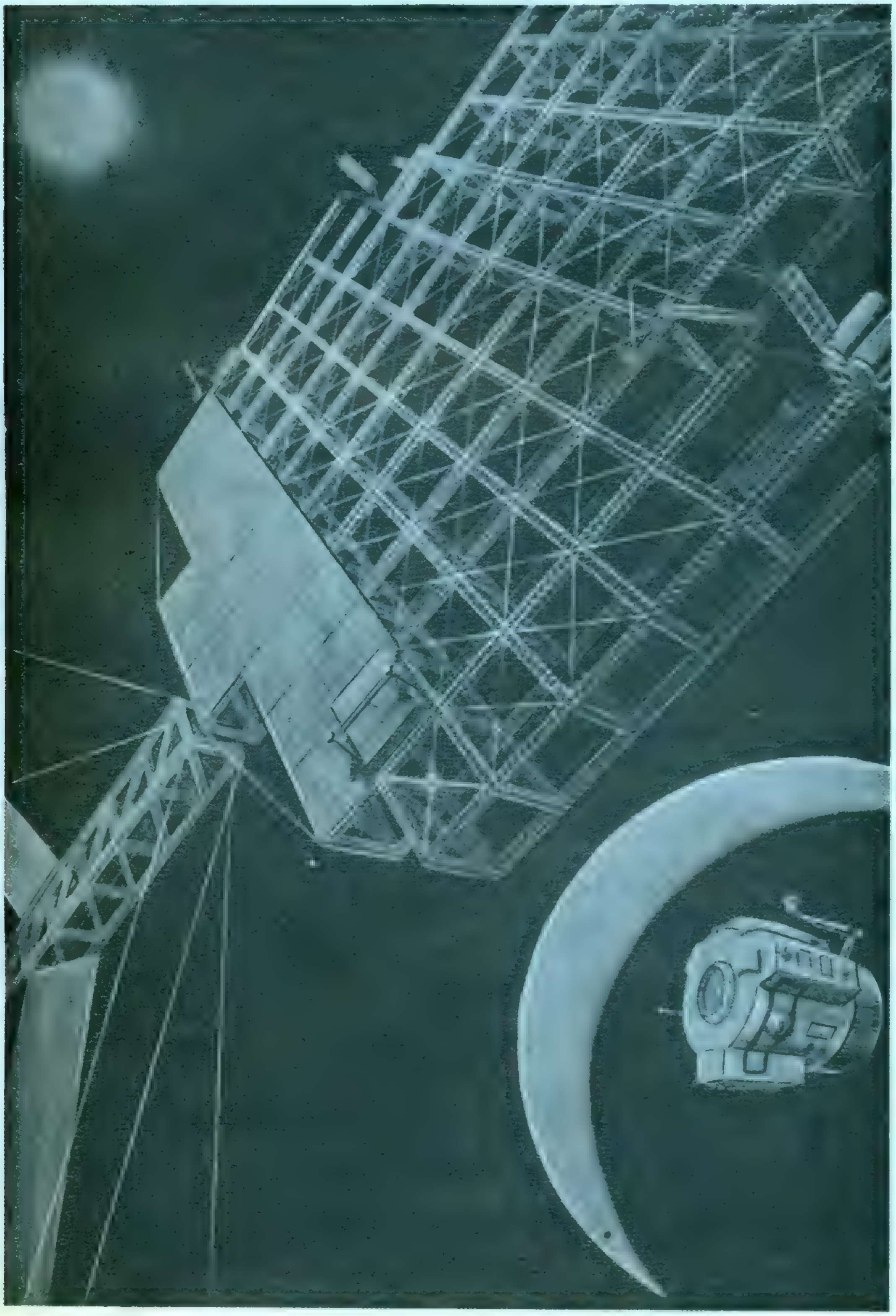
Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published for The British Interplanetary Society Ltd., (No. 402498) by Space Educational Aids Ltd., (No. 741211). Registered Office, 27/29 South Lambeth Road, London, SW8 1SZ, England.

ISSN 0038-6340

SPACEFLIGHT

VOLUME 22 No 4 APRIL 1980

Published by The British Interplanetary Society



Editor
Kenneth W. Catland, FRAS, FBIS

CONTENTS

COVER

POWER FROM A STAR. Massive Solar Power Satellites (SPS), miles in extent, could be assembled in Clarke orbit 22,300 miles (35 880 km) above the equator where unattended they would continually convert the Sun's rays into electrical energy. This unlimited supply could be transmitted to large antenna farms on Earth using microwave, laser or other technology and fed into the National Grid. The SPS concept was first put forward in the United States by Dr. Peter Glaser in 1968. It is now receiving active attention in the USA by NASA, the Department of Energy and branches of the aerospace industry in a $20 million programme. British Aerospace Dynamics Group at Bristol has been contracted by the UK Department of Industry to lead a team of British companies in studying the implications to industry of a possible future programme of cooperation in Europe and between Europe and the United States. Other participants in the six month study are Marconi Space and Defence Systems, Portsmouth; ERA Technology Limited, and BAe's Space Group at Stevenage.

NASA

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 No. 4 APRIL 1980 *Published 15 March, 1980*

MILESTONES

January 1980

10 Reported in Washington that Intelsat consortium have placed order for ESA Ariane for launch of Ford Aerospace Intelsat 5 communications satellite in December 1981 and taken an option on two more of the European launchers. Options have also been taken for Atlas-Centaur and two Shuttles.

10 Michael Collins resigns as under-secretary of Smithsonian Institution effective 28 January. Will become vice-president field operations Vought Corporation, Washington, D.C. At the Smithsonian he will be succeeded by Phillip S. Hughes, former deputy director Budget Bureau.

11 President Carter cuts Solar Electric Propulsion from NASA FY 1981 funding, placing doubt on ability to fly 1985 joint mission to Halley's Comet and Tempel II. Reason is increasing cost of Space Shuttle programme now estimated at around $8000 million at 1979 prices. NASA has already requested an additional $198 million to cover overrun in 1979, plus an amendment to its 1980 budget taking $300 million from other agency projects.

13 Shanghai newspaper *Wen Hui Bao* publishes stills from documentary film showing "China's first generation of spacemen." Five men in spacesuits are seen undergoing various tests, including simulated weightlessness. Another paper, *Liberation Daily*, includes photograph of a dog in a harness "which returned safely from a flight in one of our rockets." *There is no mention of the date when the flight was made or whether it was orbital or sub-orbital. Ed.*

14 British Aerospace Dynamics Group Stevenage Space division announces that the first two Spacelab pallets to be built to the full flight standard have been delivered to the prime contractor ERNO in Bremen. They are the first of five such pallets, the remainder of which will be completed early this year. The first flight of Spacelab is scheduled for 1982. The first flight of a pallet, however, will be somewhat earlier when a pallet with American instrumentation will be carried on a Shuttle Orbiter mission approximately six months after the first flight of the Shuttle Orbiter itself.

19 Dr. Konstantin Feoktistov, the cosmonaut and spacecraft designer, describes Soyuz-T spacecraft as being similar to earlier Soyuz craft in external appearance with many changes to the internal layout and equipment. "The onboard digital computer which does the manoeuvring and controls the systems also transmits processed data to Earth. When docking is underway, for example, the computer displays on a VDU at mission control information on how all main systems are working."
The same data are also displayed on a screen aboard the ship. A new propulsion system is embodied in which all engines — main propulsion, manoeuvre and attitude control — use a common source of propellants. Certain parts of the life support, flight control and landing systems have been changed. The use of microelectronics has made it possible to reduce the weight of radio communications, life support and thermal control equipment.

21 A new documentary film, 'Far, Far Into Space,' had its premier in Moscow recently, reports the Novosti Press Agency. The film made by Vladimir Sivkov tells the story of the epic missions flown to the Salyut 6 space station — the 96-day flight of Georgi Grechko and Yury Romanenko and

[Continued on page 154

WILL YOU, PLEASE, HELP US?

If we are to play our full part in the development of Astronautics in the 1980s, it is vital that we enlarge our membership throughout the World. We are therefore asking all members of the Society to make a special effort to assist our recruiting drive. By introducing new members you will be making a positive contribution to the BIS Development Programme. Membership Application Forms appear in the centre pages of this magazine. Please make good use of them.

SALYUT 6 MISSION REPORT – PART 3

By Neville Kidger

[Continued from March issue

Experiments of the Third Expedition

Introduction

During their 175 day flight cosmonauts Vladimir Lyakhov and Valeri Ryumin conducted many experiments in the unique conditions of weightlessness. Some of these were well known experiments continued from previous expeditions; others were new to the Salyut project. Analysis of the reported experiments and their results gives an insight into the work occupying the crews of the long term flights aboard the Salyut 6 space station.

The experiment programme is divided into sections for ease of access to any particular discipline. Many results have yet to be published and future editions of the Mission Report will hopefully bring these to the reader's attention.*

Medical Monitoring

As the Protons' flight lengthened into months the FCC medical team monitoring the men's health and well being paid specific attention to their mental, as well as physical, state.

Two types of regular evaluation were made. The first was a daily check which assessed their current state of health, working capacity and general feeling using data from radio and TV sessions, reports of their work accomplishments, dietary preferences and general mood. Every evening the doctors asked the crew 25 set questions to determine their mental attitude. This assessment became all the more vital as the crew were the first men to spend so long isolated from other people. The results showed that the crew remained full of optimism and zest for life, retaining perfectly good relations with each other. Their daily mood depended on how work was proceeding and how they got on with the FCC.

Soviet scientists stressed that there was never any tension present during conversations with the FCC capcoms. The credit for this was cited as the tremendous emotional attitude and will-power demonstrated by the crew. FCC supported this attitude by ensuring that during their off duty hours the crew did not feel cut off from the Earth. The Protons reported that they missed the Earth a great deal, particularly their families. They stressed how important the two-way TV link-ups with their relatives were. Visits of famous personalities to the FCC to speak to the cosmonauts (ranging from female singers and hockey players to scientists) were also considered important in keeping the cosmonauts psychologically "up". The mood of the FCC capcom was especially vital in this respect; if the capcom was in a good mood then this was passed onto the crew. On one rest day FCC eavesdropped on the crew solving a crossword puzzle. As if to illustrate their good frame of mind the crew had a running joke which went: "If by any chance you are late reaching our descent capsule after we touch down then look for us in the nearest village!"

Soviet specialists are currently assessing the possibilities of predicting the moods of crewmen for up to a week in the future by using computers to assess emotional data on future long duration flights.

The second type of medical evaluation was a thorough medical check which each cosmonaut carried out on the other every 8 to 10 days to provide an objective rather than a subjective assessment of their health. On this flight the terms of reference of the medical team were mainly to collect quantitive data on a particular cosmonaut's adaptation. The medical specialists worked from data telemetered to FCC from transducers on the cosmonauts bodies. The checks were so thorough that on one occasion their physician, Dr. Anatoly Yegorov, spoke personally to the crew to ask them how they happened to have a higher pulse rate during one test than the one before. The crew explained that the readings were taken in the afternoon, after dinner and a morning's work.

A typical medical day on the Salyut 6 station began with one crewman measuring the others blood circulation dynamics just after awakening in conditions of complete rest. The men then registered their body masses on the massmeter, rode on the veloergometer to measure the effects of set physical loads on their blood circulation noting the rate of blood pumping and filling rate of vessels in various parts of the body. These measurements helped the doctors predict the state and functioning of the cardiovascular system. On other occasions the men monitored each other's heart bioelectric activity with the monitoring crewman maintaining radio communication with the FCC. The major monitoring devices for these experiments were the Polinom 2M multifunctional apparatus, Reograph and Beta.

A major innovation during the flights of the Photons and Protons was the introduction of "dynamic electrocardiography" in which a crewman wears a portable cardiomonitor during physical exercises and for periods of up to 24 hours. The PCM did not restrict the crewman's movements and, together with a verbal description of his feelings, provided an objective examination of the state of the cardiovascular system.

Other medical experiments studied the behaviour of oxygen in the tissues of the body, noting the penetration of oxygen into peripheral parts of the body; there was also comprehensive research into blood circulation to obtain data on the peculiar features of the redistribution of blood in the body. In weightlessness blood tends to collect in the upper torso instead of being evenly distributed around the body. To aid the analysis the crewmen donned the hermetically sealed "Chibis" suit which, once pressurised, allowed measurements to be made of the blood circulatory system and allowed an assessment of cardiac activity. To a certain extent the "Chibis" suit simulated the bodily distribution of blood under normal gravity.

As an effect of this redistribution of blood, after about one month of the flight, the volume of Ryumin's tibia had decreased "a little". Soviet physicians explained that this was because "being a tall man (Ryumin's) blood redistribution takes place in a different way than that of the smaller Lyakhov."

Whilst the cosmonauts' functions remained unchanged slight reductions were noted in their erythrocyte (red blood cell) count and in their immunity. The erythrocytes are reproduced entirely over a period of 120 days, practically all of the erythrocytes formed during the flight. Examination showed that they fully retained their function of oxygen carriers giving doctors the confidence to expect that other generations of erythrocytes formed in space would do the same.

In other areas the doctors noted a lowering of the crew's immunity to certain diseases (i.e., flu, etc.) and further research is needed to define what is required to overcome this problem. There was no evidence of cell division impairment.

Exercise Programme

The Photons readapted after only 7 days on Earth. As a result of the previous flights the physicians amended the daily exercise routine the Protons would have to follow to enable them to fulfil their 6 month stint in space in good health.

The Protons began, after only about two weeks in space, an expanded exercise routine which lasted for 2 to 2½ hours per day at a level of 150% more than the earlier crews. During this daily period each crewman was obliged to "walk" for 4½ km and "jog" a further 4 km on the treadmill, in addition to exercising on the veloergometer. For the treadmill exercises the crew wore special costumes with a magnetic attachment to the floor and rubber shock absorbers with a force of up to 50 kg to keep the cosmonaut on the track. The men also made use of the on-board chest expanders for 30 minutes per day.

For 10 hours or more every day the crew wore the established

References and acknowledgements as Part 1.

RECORD BREAKERS. Cosmonauts Vladimir Lyakhov and Valeri Ryumin are interviewed on 19 August 1979 immediately after their epic space flight lasting 175 days 36 minutes. To help them re-adapt to Earth gravity conditions they were placed in reclining chairs at the landing site where on-the-spot medical examinations were made before the men were transferred to the Tyuratam-Baikonur cosmodrome by helicopter.

Novosti Press Agency

"Penguin" training suits which comprised a normal flight garment with rubber bands stitched in to pull on the muscles and thus create a load on "the supportive – motor apparatus and skeletal muscles". This to an extent compensated for the lack of gravity.

The expanded exercise routine on the earlier flights had signalled the approaching end of the flight but with the Protons the idea was to establish a fitness level and maintain that throughout the flight.

The cosmonauts themselves were not altogether happy about the exercise routine, which they characterised as "difficult", but took very seriously "knowing that their very existence in space depends upon their physical fitness and well being.... As flights become longer, with greater demands on the crew, the pre-flight training routine will be stepped up and assume an even greater significance", said Dr. R.V. Dyakonov. With the Protons FCC assumed more control over the timing and duration of the exercise routines and the medical team praised the crew's "professional approach" to the programme. As the mission planners were still "feeling their way", concerning the amount of exercises to schedule, the men were allowed a certain amount of free choice in the type of exercises they did.

The cosmonauts soon found themselves ahead of their schedule for the exercise regime but, the physicians stressed, previous experience had shown that such a reserve was necessary. The routine had the effect of actually making Lyakhov and Ryumin physically stronger and they maintained their medical parameters at the same level as on Earth. Their cardiograms resembled those of well trained athletes.

The training methods were aimed chiefly at maintaining muscle volume by applying the training to the muscle system as a whole. Soviet physicians noted that the muscle system comprises two parts, one for rapid random movements and the other, called the tonic muscle series, for control of body posture and position in space. The exercise routines of earlier crews had stressed the muscle system as a whole without emphasis on the stabilising muscles with the effect that these muscles tended to lose part of their mass. The Protons' exercise regime was aimed at "maintaining the health and strength of the tonic muscles."

The excellent health of Lyakhov and Ryumin throughout the mission was confirmed in flight by their reactions to set physical loads on the veloergometer. Pre-flight measurements of an individual crewman's performance were compared with telemetered flight measurements at the same load. Whereas, after about a month in space, some of the earlier cosmonauts had shown some worsening of their reactions to these tests the Protons maintained their pre-flight levels throughout, a confirmation of the amount of exercise time allotted to them, and the personally tailored regimes of work and rest. Physicians noted that methods of prophylaxis and control were, of necessity, becoming more individualised.

To maintain their bone strength the crew's diet included foods with a high calcium content to partially compensate for the calcium "washed out" of their bodies in space. The diet of cosmonauts Lyakhov and Ryumin included about 70 meat, dairy and other products, such as confectionary, fruit and spices. In addition they received fresh fruit and vegetables from the Progress ships to add to the onions, dill and parsley they cultivated in their vegetable garden aboard the ship. Salyut 6 crews were allotted about 300 calories per day more than the Salyut 4 crews bringing their average daily intake up to 3100 calories. Two ovens were available in which to heat food contained in special tins. The average daily water intake per man was about 2.5 litres, including water in solid foods. The crew also had two vitamin preparations to improve their metabolism; one to improve their cardiac muscles, the other to make up a potassium deficiency. In order to further strengthen their cardiac muscles the crew received, by Progress 7, new types of "penguin" suits. They created a load on the muscles even when the cosmonauts were motionless rather than solely when they moved as the previous design had done.

Efficiency

By the third month of the flight the crew were sleeping somewhat less than they had been previously (7 to 8 hours per day as against 10 hours). Ryumin, who usually went to bed late on Earth, retained the habit in space. The work programme was planned to give the cosmonauts about the same amount (averaged out over the flight) as that performed by the previous

Salyut 6 crews. The men maintained throughout a desire to work and, later in the flight, felt a need to perform above the amount of work scheduled. At times FCC was concerned that the crew would exhaust themselves with this desire and told the crew to adhere strictly to the work/rest cycle. The FCC physicians noted that giving the cosmonauts too much work to do would leave them in the same physically and emotionally unstable state as they would have been with too little to do. With the pressure to try and beat the flight plan schedule removed, the crew's efficiency began to improve. This impressed the FCC specialists and may lead to an increase in the volume of work scheduled for later crews if the trend is repeated on later flights.

Weight

The weights of Lyakhov and Ryumin, assessed daily on the massmeter, showed slight variations during the flight. Lyakhov, who was slightly overweight at the start, lost a total of 5.5 kg including 2.3 kg during a nine day period in mid-June. He joked that he would have to fatten up before the end of the mission.

Ryumin, normal weight 84 kg, maintained this average for the majority of the flight and, in mid-July, actually put on 700 g. This was the first time that weight had been gained on a long duration flight. Ryumin was said to have weighed the same when he landed as when he was launched, prompting him to say that he thought the problem of weight loss had been solved. It seems more likely that this was simply an individual phenomenon and that other crews will lose weight similar to Lyakhov. At the same time the size of the cosmonaut's lower leg decreased by about 20%. Soviet physicians stress that this is an unavoidable feature of weightlessness. The weight differences also manifested themselves at touchdown. For the first few days on Earth Ryumin was the healthier of the two cosmonauts and was walking some time before his commander.

The overall radiation dose during the flight constituted 6 to 7.5 rbe, a fraction of the admissable level. Watch on the radiation levels in near-Earth space is maintained regularly by small scientific satellites of the Cosmos series.

OBSERVATIONS OF THE EARTH

Visual Observations

Earlier Salyut flight crews became "absorbed" in their programme of visual observations of the Earth's land and sea surfaces to the extent that it became their favourite pastime even during the training flights on Tu-134's.

For the first few days of their flight the Protons were compelled to use a map to locate surface features but they soon adapted, arriving at the "habit forming" stage of observations earlier than the three weeks it had taken previous crews.

The men noted late in the flight that it was quite easy to accurately determine the co-ordinates of a particular area or surface feature if it lay beneath the ground track of the station. It was not so easy if features lay to either side of the station. The crew recommended that specialists examine new methods, or even design an instrument, to make the work more accurate.

The Protons' visual acuity was good. They described how, on one occasion, they were able to see all of the major highways spreading out from Moscow and even spot familiar streets. Occasionally they pointed the TV camera out of the windows and sent live colour TV to FCC together with a running commentary. This technique had first been tried by the Photons and scientists had declared it a very useful tool in Earth studies. The crew found that the changing seasons enabled them to better observe geological formations. The two men even became adroit at predicting weather for the coming days. On one sunny day over Moscow the crew said that by the weekend it would be raining and, as promised, it was raining at the weekend.

To avoid fuel wastage during their observation periods Salyut was usually put into a gravitational stabilised mode which had the added advantage of allowing them to see the Earth from all sides of the station. Specific features observed included:

- A previously unknown global fault traversing Africa. Photography of the remoter regions of the African continent is difficult from aircraft and detailed photography is yet to be scheduled from space of the continent.

- Forest fires in the Siberian Taiga. On one occasion the crew radioed the coordinates of a fire to FCC. The cosmonauts were the first to spot the fire near Lake Baikal and the quick despatch of firefighters from Khabarovsk Kray to the area saved many thousands of valuable trees from destruction.

- Cyclonic formations affecting the weather in the European USSR following their formation in the northern Arctic. The cyclones observed in the Atlantic were preceded by a characteristic whirling of clouds with a central "bright eye".

- Plumes from bush fires in Central Africa were seen to be carried in the upper atmosphere to South America.

- Volcanic activity, monitoring the March eruption of a volcano near White Island, New Zealand and the April eruption of Mt. Soufriere, St Vincent; also measuring heat from Mt. Etna.

- Studies of wind-blown dust storms to aid in assessing the effect such storms had on the climate. The Photons had seen dust transported in the upper atmosphere from Africa to North America.

- Observed areas of major industrial construction in the Volga region, N. European areas of the USSR, Siberia including the Baikal-Amur Railway (BAM) and the Soviet Far Eastern region.

- Oil slicks from the July double tanker collision in the Carribean and the Mexican oil well blow-out.

Oceanology

Earlier Salyut flights, together with correlated data from tracking unmanned geodetic satellites, had discovered gigantic elevations and depressions in the level of the world ocean. The crews had also noted that large ocean currents and eddies were easily observed from the vantage point of space.

Once the Protons had "learned how to see the ocean" they became adept at observing many of the transient features in it, spending much of their off-duty time chatting to oceanologists based at the FCC. The cosmonauts made a detailed study of the currents in the Volga estuary and Black Sea areas, also mapping the shore-shelf washed by the seas near the USSR.

The Protons' most valuable observations, however, were of plankton fields in the Atlantic and Pacific oceans. These areas, where vast shoals of fish assemble to feed on the plankton, were characterised by areas with apparent changes in the ocean surface colouring which marked the interface of warm and cold currents. On his flight Vladimir Kovalenok had had twice-weekly discussions with members of the fisheries research staff to tell them of his observations. The Protons continued this good work efficiently directing fishing fleets to the best areas for fishing. The Soviets claim that after acting on such information three trawlers caught 38 to 45 tonnes of fish each day for three successive days in the Atlantic. On another occasion 11 trawlers managed to net an aggregate of

SPACE CADETS. Two previous visitors to the Salyut 6 orbital laboratory were the veteran Soviet cosmonaut Pyotr Klimuk and the Polish cosmonaut Miroslaw Germaszewski who flew in Soyuz 30. Here the sons of the cosmonauts Misha Klimuk, 9, and Miroslaw Germaszewski, 10, model their fathers' space suits.

Novosti Press Agency

EARTH RESOURCES OBSERVATIONS made by Soviet unmanned satellites and Salyut space stations are yielding large amounts of information useful for the development of agriculture, meteorology, oceanography and geology. The results are being coordinated by the Nature Resources Space Research Institute within the Academy of Sciences of Azerbaidzhan. Above, powerful lenses, made in East Germany, help researchers decipher the space pictures.

Novosti Press Agency

2,046 tonnes of horse mackerel in three days. The only equipment the crew used to aid them in this work were spectrometers and an infra-red camera to spot the thin film of oil which tends to form over the fish in warmer waters. Such practical work was very popular with the crew who were often briefed on the results of their recommendations. Ryumin suggested that the pre-flight training be intensified in this area; it took them 1½ months to learn. The cosmonauts spotted dynamic features of the ocean including a "wall" of water hundreds of kilometres long and about 8 km wide rising above the surrounding surface level in the Timor Sea near Australia and a 100 km long 1 to 2 km wide 1.5 to 2 m high upsurge of water along the equator (defined by its shadow) some 250 to 300 km from the East African Coast. Specialist concluded that these phenomena were caused by the collision of two wave fronts against a background of warm water. Similar ocean features were spotted and photographed by the Skylab crews and an interesting selection of these observations is documented in the book *Skylab Explores the Earth*. The Soviet cosmonauts managed to observe a large trough in the ocean near the Caroline Islands.

In an experiment remarkable for its foresight the cosmonauts were asked to look out for and map deliniations in the ocean caused by currents which divided the ocean into small zones with differing characteristics. Soviet specialists are attempting to find suitable areas where fish breeding within natural instead of artificial barriers can be conducted.

Upper Atmospheric Research

The Protons' programme of upper atmospheric research was an extension of the work done by the earlier Salyut 4 and 6 crews. The cosmonauts concentrated on logging features of the atmosphere involving the density and pollution in its upper layers using the Bulgarian Duga and Spektr-15K instruments. The Duga instrument was used at orbital night, Spektr by day.

Duga was a small optical electrophotometer. For observations the cosmonaut aligned the optical finder telescope at the target. The light, after being allowed through the reflecting telescope, passed through light filters where it was magnified and registered on a recorder unit in various spectral bands.

The instrument was designed to record specific targets of the upper atmosphere which were:

- the first and second emission layers along the velocity vector and equatorial regions.
- luminous red ionospheric arcs arising after severe magnetic storms.
- vertical structure of the main emission layers in the aurora, and
- stable luminous arcs in the plasmosphere.

The Spektr-15K (Spectrum) instrument recorded reflected light from the Earth in 15 spectral bands in a technique analogous to multi-spectral photography. Ocean boundaries and plankton accumulations were able to be spotted with the device which was also used to obtain atmospheric spectrographs above industrial areas to determine pollution. In auroral studies the crew reported seeing, for about 15 minutes each at least twice during the flight, "a very beautiful, highly coloured aurora". Ryumin describing the phenomenon, said that while usual aurora usually appear faded with respect to their colours this time there was a positive "riot of colours", from carmine through green and other colours and ending with white.

The Protons were also able to record a multicoloured phenomena similar to the aurora with spectrum-like colour boundaries first reported by the Taymyrs; they noted the appearance of noctilucent clouds over the equatorial regions (normally they are seen over the polar regions almost exclusively); continued the study of the strange silvery clouds which earlier cosmonauts, using a micron instrument, had shown to be made up of silicon particles combined with water molecules at a temperature of −130°C. at a height of about 80 km; observed the second emission layer, shooting a second series of films when the first film, returned on Soyuz 32, had been shown to have spoiled through light spillage.

Earth Resources Study

The Protons' programme for the study of the Earth's natural resources included regular surveys of selected areas of the USSR with the fixed MKF-6M and KATE-140 cameras. Over 60,000 photographs have been taken of the Earth with the MKF-6M camera alone from Salyut 6. In addition soil moisture content and sea surface state was studied, amongst other things, with the KRT-10.

Salyut 6 produced Earth resources data has aided in:

- Forecasting snow melt run-off and soil moisture content in agricultural areas of the Ukraine, Urals and Kazakhstan. This aids crop growth assessment and harvest yield forecasts.
- Monitoring the movement and behaviour of the USSR's longest glaciers including over 2,000 logged in the Caucasus. Salyut 6 crews are aiding in the compilation of a snow and ice atlas of the world for UNESCO.
- Production of updated tectonic and seismic maps of the USSR including the BAM route.
- Assessing the timber wealth of the Siberian Taiga. Computer analysis of photographs is used to classify tree species, age and timber quality as well as determining their number. The Soviets have assessed over 7,000 km² of Taiga this way.
- Discovering oil and gas deposits near fault lines. An oil field in Dneiper-Donetsk was discovered as a result of "roentgenoscopy" of a space photograph. The deposit was invisible from the high flying aircraft collecting ground truth data. Other areas of study have included the Urals, where gas deposits have been found, the Pripyat Deep and Caspian Turkmenia. Within five months of last year 34 possible oil deposits were identified from Salyut photographs. This contrasts with the 60 years it had taken Soviet experts to discover 102 deposits by more traditional methods.
- Drafting a programme of soil cultivation and environmental protection for the Mangyshlak Peninsula where vast subterranean fresh water deposits have been discovered.
- Recultivation of innefficient pasture farms on the shores of the Caspian Sea.
- Identification of circular features akin to eroded impact features on the Moon. Smaller examples in the area of the Sea of Okhotsk are related to mineral deposits.

The cosmonauts worked to a special roster containing a detailed programme for the compilation of a natural resources inventory of the USSR common to all Salyut crews. Ground truth data from aircraft and ground teams are supplementing the space collected data. Such information has already been used in the construction of hydro-electric power stations.

Salyut data is used in conjunction with data from GDR-made spectrographic instruments carried on the Meteor 2 series satellites and photographic, TV, radar and laser scanners

carried by satellites of the Cosmos series studying Earth's natural resources. Such satellites are now launched frequently by the USSR.

BIOLOGICAL EXPERIMENTS

Botany

The botanical experiment programme occupied a small fraction of the cosmonauts' time in orbit but proved to be one of the most rewarding forms of relaxation. The cosmonauts' functions related to this series of experiments were simply to change the atmosphere in the biocontainers and feed the plants nutrient as well as monitor the equipment.

Plants grown on previous expeditions had shown some unusual formations. Mushrooms, for example, grew with long curly stems. Along with onions, dill, parsley and fennel, the mushrooms were also a supplement to the crew's diet.

Seeds of the aribidopsis plant were injected in a nutrient solution in a 2nd Fiton (or Phyton) unit delivered by Progress 5 with the space seed drill. The unit was then placed near to a light source. Botanists discovered that, despite their short life cycle, the plants were unable to provide seeds in space. This is thought to relate to the plant's inability to dispose of their waste products, i.e. they "choke" on their own waste. Botanists have also noted the destruction of cell structures within plants. Further experiments to confirm theorists views on the problem were spoiled late in the flight when plants in a 3rd Fiton unit, delivered by Progress 6, were found to have been withered by the lights for a TV broadcast. The 3rd unit had been placed closer to the light source with better ventilation to determine the effects this had upon the plants. The experiment will probably be repeated later.

The cosmonauts planted a real tree aboard the station. Botanists expected it to develop normal roots, trunk and leaves, as it would do on Earth. But the tree would stand no higher than 10 cm even when fully developed.

The cosmonauts planted tulips in their "hot house". One tulip, almost in bud was delivered by Progress 6, several others in a container by Soyuz 34. By the end of June the tulips were on average 52 cm high although the buds stubbornly refused to open. Buttercups alongside of them were blossoming however.

In their Oasis instrument (similar to those carried aboard Salyuts 1 and 4 and Soyuz 13) wheat and peas were planted. Growth pattern of these plants had, in earlier experiments, yielded some (unspecified) contradictory results. By 13 July the crew reported that the peas were some 12 cm in height; wheat grew to over 30 cm in 15 days. The container with the plants in was shown on TV.

Research on microscopic plant life was continued on Salyut 6, this time concentrating on the growth of the seaweed chlorella which scientists are hoping to use for food on flights to the planets. The results of two different types of experiments showed that the growth of the plant in space was slightly better than its Earthly control counterpart. Botanists attribute this to its aquatic origin. On the other hand moss showed a tendency to grow more slowly in space than the control samples. The reason for this is thought to be an adaptation of the organism's biorythmic control altering its aging process.

With the series of disappointing results surrounding plants grown in complete weightlessness it was natural that botanists should wish to place a device to create artificial gravity in space. A small centrifuge was carried in both the Cosmos 782 and 936 biosats during their flights in 1975 and 1977 respectively. The results of the experiments were hampered slightly because of the poor attitude control of the vehicle which allowed the gyroscopic effects of the centrifuge to cause an ever increasing tumble of the entire craft.

With this in mind Soviet specialists placed on Salyut 6, *via* Progress 5, a small centrifuge called biogravistat which consisted of two plates – one of them stationary, housing control specimens, and the other rotating.

In previous orbital gardens the plants had generally not been able to proceed beyond the stage of germination; they grew from seeds but did not produce seeds of their own. Experiments conducted on earlier flights saw cucumbers and garden radishes sprout but then perish within a couple of weeks. Onions were a notable exception. The biogravistat instrument was frequently in use by the crew to grow seeds delivered by Soyuz 34 and the Progress ships. The crew noted that moistened plant seeds on the rotating plate showed a tendency to grow twice as quickly as those on the stationary plate with the roots developing directly along the radius in the direction of the centrifugal force (this is similar to normal experience where the roots develop towards the centre of the Earth). In the case of the cucumber seeds the roots of the stationary (control) plants were only half the size and length of those on the rotating plate. In addition the stationary plants had roots growing haphazardly in any direction. The first experiments on the biogravistat had seen the cucumber seeds put out long stems with yellow tips which quickly perished. Parsley seeds had small roots which failed to grow in the required direction. Garlic shoots reached a maximum length of 30 cm with onion shoots reaching a maximum of 20 cm.

In a repeat of earlier experiments with lettuce seeds and borage seedlings the borage was developed on the centrifuge and then transferred to the normal Oasis installation from where it was eaten by the crew. Many samples of the plants were taken and packed in biocontainers for later examination on Earth. One of the first discoveries was that wheat germinated better in weightlessness.

Life Sciences

Experiments on the effects of weightlessness on micro-organisms were continued by the *Protons*. For example the series of experiments on the hereditary of *Drosophila* are now standard to all long duration flights. The small fruit flies lend themselves readily to such genetic research as they produce a new generation almost every fortnight. The biocontainer is a small thermostat "house" called bioterm, which ensures an optimum temperature of 24°C. The larvae are fed on a nutrient medium, resembling a treacle, made from raisins and yeasts.

One of the flies, which the crew affectionately called "Yurka" was shown to the TV audience through a magnifying glass in early June after it had been awakened from "the slumbers". The primary results of the *Drosophila* experiments show that there is indeed a marked increase in the development of the flies.

Experiments with tadpoles and the *Iroteidae* micro-organism showed interesting (although yet to be made public) indications of how spaceflight conditions affect living things.

The most sophisticated biological experiment yet carried into space was performed by the Protons – at their own request! Soviet specialists had planned to launch into space, aboard the next Soviet biosat, an incubator in which quail embryos would be allowed to develop. This experiment so intrigued Lyakhov and Ryumin that, before their flight began, they asked for an incubator to be built and put in Soyuz 32 for them to take to the Salyut. The cosmonauts took with them 8 quail eggs and, once aboard Salyut, they put the eggs into the incubator to watch them develop. Control samples were kept on Earth. The control samples hatched normally but in space the crew found that the chick embryos had developed far slower than on Earth and with a body but no head. The crew returned the samples to Earth on Soyuz 32, new samples having been delivered on Soyuz 34. Speculating on the results a zoologist said that artificial gravity may well have to be produced to allow normal development of the chicks. The ultimate aim is to create a poultry farm aboard a space station. The results of the quail eggs incubated for a period of three days before the Soyuz 32 spacecraft was returned with them

on board, and the later samples delivered by Progress 7, were not available at this writing.

The crew began, in June, a second series of experiments with the French-made Cytos experiment to study the growth of micro-organisms in weightless conditions. The first series of experiments, conducted during the Pamirs' flight in January 1978 showed that even in the presence of the appropriate nutrient medium bacteria did not develop any faster in space than on Earth. At the same time researchers noted that the simplest organism showed a "quite significant" acceleration of growth.

Astronomical Observations

The Protons conducted pioneer work in the fields of gamma ray and radio astronomical observations during their 6 month tenure aboard Salyut 6. In addition limited use was made of the 650 kg BST-1M submillimetre telescope during the early portion of the flight.

Development of a working procedure for the BST-1M had been a prime requirement of the Taymyr and Photon crews. The reports and notes made by the Taymyrs had led to more precise recommendations for the Photons who in turn created their own methods for orientation of the complex during the operation of the BST-1M. The first task for the Protons was to calibrate the instrument. For this to be achieved the telescope was focussed onto a well-known source of emission, i.e., Jupiter, the Moon, Earth's twilight horizon, to determine the quality of the magnetic recording to distinguish between signal and noise. This enabled them to assess the remaining sensitivity of the receivers (radiation with a wavelength of around 1 mm is difficult to distinguish against a background of thermal pulses). Pointing accuracy of the telescope is 1 minute of arc. To determine the telescope's function the Protons observed the star *Sirius*. The telescope was found to be working well. There appear to have been problems earlier in the flight with the instrument's performance in the infra-red wavelength during which the receiver crystals are cooled to −273°C. For this reason the major activities of the telescope were in the ultra-violet wavelength.

Although stars emit in the UV the telescope's major function in the third crew's flight was the registering of the UV emissions of *Beta Centaurus*, not to study the star, but to record how its UV emissions are blocked by the ozone in the Earth's upper atmosphere to determine the ozone layer's density. At about 90 km above the planet the ozone layer is thought to be thinning and thus allowing more UV radiation from the Sun through to the surface of the Earth. Studies of the density of the layer will record the amount of the depletion (if any). The planet Jupiter was also used for these studies.

To operate the telescope Ryumin straddled the cone and pressed buttons after lining up the 1.5 metre dish in the direction of the object to be observed. Lyakhov controlled the orientation of the station while the information was collected and telemetered to the FCC.

Other important geophysical information collected with the BST-1M included studies in the submillimetre wavelengths of the amount of water vapour in the atmosphere, particularly in the tropical zone where the main trade winds create currents and seats of disturbances or tornadoes of various sizes. These data will aid in satellite forecasting of cyclones.

The Protons used, for the majority of the flight, a portable gamma ray detector (the Soviets call it a telescope) which was christened Elena. This instrument was delivered by Progress 5 and was designed to measure the intensity and direction of gamma ray fluxes. Its purpose was to provide information about the physical conditions in which future large aperture gamma ray telescopes will be working in space. Thus Elena demonstrated the same basic characteristics of these proposed telescopes on a small scale.

The Elena experiment was called "Gammafon" (gamma background) and related to the primary purpose of the detector. In the experiment Soviet scientists studied the streams of high energy gamma quanta which exist around and in the spacecraft arising from the interaction of cosmic rays with the upper atmosphere and spacecraft structure. To obtain measurements of the background radiation at various locations and times during the flight the cosmonauts periodically relocated the detector in various parts of the space complex.

Elena was developed and built by students of the Moscow Engineering and Physics Institute working in the Laboratory of High Energy Physics Problems under Prof. Kiril Ugryumov.

The KRT-10 radio-telescope

The Progress 7 cargo spacecraft delivered to the complex a 10 metre diameter radio telescope weighing about 300 kg. The experiment programme for the device, the first of its type ever flown in space, was described earlier. Soviet scientists see the KRT-10 as only the first step in a programme which will see larger and larger diameter radio telescopes erected in space. The future telescopes will probably have to be assembled in open space from components delivered to an "assembly orbit". The KRT-10 differed from these large radio telescopes in being assembled inside the Salyut. The telescope comprised a highly directional dish antenna, supporting mast, five radiometers, a time block, recording and processing apparatus and a control panel.

The reflector had a diameter of only 50 cm when furled, opening out to the full 10 metres. Constructed from "a canvas of metallic wires" 50 microns in diameter the antenna had a weight per 1 m² of less than 1 kg. At its focus was a "hermetically sealed container receiving high frequency signals". A thermal control device was used to regulate temperatures. It had a reception quality of about one-tenth of a millimetre. The fact that only high frequency signals were studied was due to the lack of penetration of low frequency signals (below 1 cm) through the atmosphere. Simultaneous studies with the 70 m dish in the Crimea are therefore only possible above the 1 cm wavelength. The future Soviet radio telescopes in space may concentrate on the reception of low frequency waves as the US RAE-A and B satellites have done following their launches in 1968 and 1973 respectively.

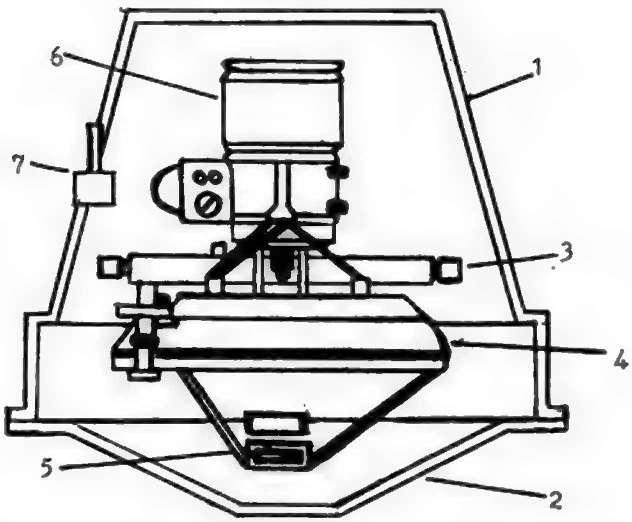
Materials Processing Experiments

The Protons conducted an extensive series of materials processing experiments which extended those performed on the ASTP and earlier Salyut 5 and Salyut 6 flights. The crew used three furnaces, the Splav-01 and the Kristall used by the Photons. An improved Kristall furnace was delivered by Progress 6. 54 smeltings of semiconductor crystals were accomplished during the 175 days of the flight with the major aims of:

- producing semiconductor elements for the electronics industry;
- producing homogenous mixtures with differing specific gravities, and
- continuing the Soviet/Bulgarian and Soviet/French co-operative experiment programmes.

As specific examples of the utilisation of the Salyut-produced materials the Soviets cited the use of crystals of cadmium and mercury tellurides in the heat detection system of a body scanner called "thermovisor' and the experimental industrial production of semiconductor crystals from elements of the 3rd and 4th groups of the periodic table such as gallium arsenide and indium antimonide. The former are used as solar battery elements and have demonstrated increased performance. Certain Salyut-produced crystals have demonstrated abnormally high growth rates.

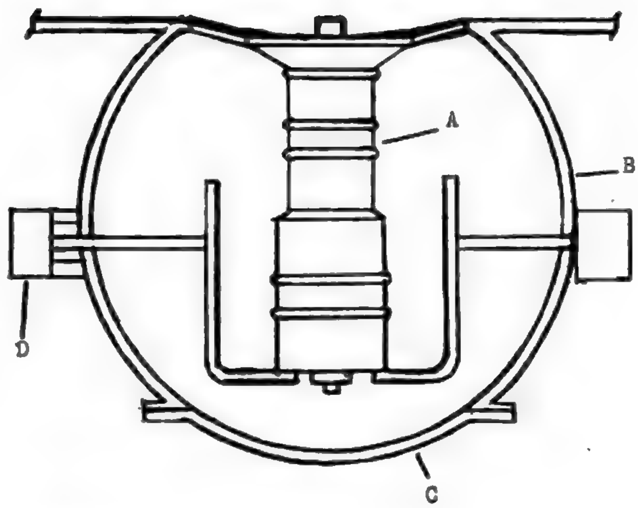
The Soviets claim that space grown monocrystals are ideal



BST-1M TELESCOPE. The largest item of scientific equipment aboard Salyut 6 is the BST-1M telescope used for studies in the ultraviolet (0.2–0.36μm), infrared (60–130μm) and submillimeter (300–1000μm) wavebands. The telescope, suspended in a gimballed mount, is able to be tilted by 10 deg in the vertical and horizontal planes.

Key:
1. Protective cover within the station.
2. Protective cover outside the station which is moved aside during data collection periods.
3. Mechanism for winding the BST-1M outside the station.
4. Main screen 1.5 metre diameter.
5. Secondary screen with cover.
6. Cryogenic cooling system for cooling the receiver crystals.
7. Optical viewfinder.

Drawing by Lynne Hill from an original in "Aviatsiya i Kosmonavtika".



THE SPLAV-01 FURNACE.

Key:
- A. The Splav-01 unit.
- B. *Shlyuzovoy Kamera* (Sluice Chamber) No. 1.
- C. Hatch for entry into the Sluice Chamber.
- D. Mechanism for winding the Splav-01 unit into and out of Sluice Chamber.

Drawing by Lynne Hill from an original in "Aviatsiya i Kosmonavtika".

semiconductors demonstrating high purity and crystallographic perfection. In addition the possibility of controlling the electrophysical properties of 3-dimensional monocrystals is making possible the construction of improved semiconducting instruments used in the production of integrated circuits. This advance in technology is allowing the Soviets to claim that the density of semiconductor elements on a transistor plate 1 mm², which is at present about 100,000, will lead to up to 1 million elements on the same plate by the late 1980's. The savings in weight and power of the device using these transistors will be quite substantial if this is achieved. The Soviet electronics industry uses only a few kilos of semiconductors per year and the improvement in quality of space-produced crystals justifies the cost of putting the furnaces into space, the Soviets claim.

A 5 to 6 fold improvement in the structure of terrestrial produced crystals has been demonstrated on Salyut 6. The dislocation density, which is a measure of the crystal's imperfection in relation to the displacement of the individual atomic layers compared to their theoretical arrangement, was some 1,000 to 10,000 times less in space-produced crystals.

In the near future the Soviets are hoping to produce new semiconducting, magnetic, superconducting and emissive materials in space. The first superconductor niobium, aluminium and germanium was produced by the Protons late in the 175 day flight. In Soviet long term planning scientists envision automatic materials-processing spacecraft, visited only occasionally by men to supply new materials and return the produced samples to Earth.

ELMA and PIRIN

In addition to their domestic programme of smelting experiments the Soviets asked for samples from France to be smelted in space. The Bulgarians also provided materials for the Protons to smelt. The latter were to have been smelted during the flight of Georgi Ivanov and Nikolai Rukavishnikov.

The French "Elma" series of smeltings studied substances not covered by the programmes of the Intercosmos countries' research programmes. 10 ampoules were prepared in Tolouse using rare substances and were delivered aboard Progress 5. Eight of the ampoules were smelted in the Kristall furnace at temperatures of up to 1100°C, with cooling times of up to 24 hours. The other two ampoules were smelted in the Splav-01 furnace with the Salyut thrusters deactivated to avoid any disturbance to the molten samples.

The materials in the experiments obtained:

- monocrystals of germanium and vanadiam oxide;
- magnetic materials such as alloys of magnesium, cobalt and other metals which do not normally combine in gravity;
- aluminium-copper and aluminium-tin;
- aluminium-copper and aluminium-lead;

The experiment sought to obtain effective magnetic alloys from materials impossible to mix on Earth. In the experiment conducted in the gradient zone of the Splav-01 furnace the spherule of metal hung on a small metal filament, owing to the effects of surface tension, so that it is located at a specific spot. The processes within it take place in accordance with temperature changes obtained in the furnace – a new way of obtaining such spheres. The returned samples were examined by Soviet and French researchers.

Bulgarian scientists named their series of smelting experi-

ments "Pirin" and used such metals as zinc, selenium and tellurides to obtain semiconductor elements. An experiment conducted in the Splav-01 obtained, for the first time, foam metals which exhibited a low specific weight whilst demonstrating softness and comparatively high mechanical properties.

Spacecraft Habitability

Probably because of the amount of repair work they had to do during the flight, the Protons became highly proficient at supplying the ground with progress reports on the state of the station. Ryumin, as one of the designers of the station, was in an excellent position to offer constructive criticism about the positioning of certain items of equipment and controls. All three long-stay crews made various suggestions concerning how the station might be improved and these are being taken into account by the Salyut designers for the next generation of space stations.

During the flight of GDR cosmonaut Sigmund Jaehn an experiment called Audio was performed. The aim of this experiment was to determine the sensitivity threshold of human hearing in spaceflight conditions. For no apparent reason this threshold proved to be lower than it was on Earth. The Protons therefore spent some time measuring noise levels in the station, which had been designed to be quieter than earlier versions. However, with dozens of fans running and equipment operating automatically Salyut 6 was still quite noisy. This background noise, although the cosmonauts said they readily adapted to it, worried the specialists as it had been determined that noise had an effect on man which is in part independent of his awareness of it. Again, the data collected from these experiments will assist the design of future space stations.

In other areas relating to the design of Salyut the crew measured the effects of solar heating on the spacecraft structure using optical devices in Salyut and Soyuz 34 after the station had been put into a solar stabilised mode, allowing the Sun's heat to warm one side of the station continuously for one "day" orbit. The men were also required to note micro-meteoroid impacts on the surface of the station. To achieve this they took photographs through the windows to determine how meteoroid impacts had degraded them and sent a mould of a meteoroid impact on one of the docking units to Earth in Soyuz 32. Konstantin Feoktistov noted that over the 300 days of its exposure to space a micrometeoroid detector retrieved by the Photons had revealed almost 200 impacts. The data showed that a constant "rain" of small particles was hitting the ship, far more than expected. Examination of Soyuz 32 also revealed far more impacts than had been anticipated. The cosmonauts saw at least one small impact crater on the windows of the Salyut.

Other experiments related to future spacecraft developments involved two devices flown to the station on Progress 7. The Resistance experimental unit measured the load factor on the station arising from upper atmospheric drag. Data gathered in this experiment it is hoped will lead to better determination of orbital parameters and predictions of orbital decay.

The cosmonauts used the second device, called Vaporiser to experimentally coat various surfaces with aluminium. The vaporiser instrument was installed in airlock no. 1, which was unsealed and controlled from inside the station. Small titanium discs were given a silver coating by evaporation and condensation of the aluminium. The experiment, which yielded about 15 samples, is seen as the forerunner of a device to be used on future space stations to renew thermal reflecting surfaces as well as being used in optical and electronic devices.

Other future directions of the Soviet space programme to emerge during the 175 day flight were the disclosures that future communications links with the orbital stations will be continuous (probably by means of geostationary communications satellites), and that Soviet space planners are considering introducing an "Aeroflot type" of management and operations when the launching of manned spacecraft becomes commonplace.

[To be continued

MILESTONES/continued from page 145

the 140-day flight of Vladimir Kovalyonok and Alexander Ivanchenkov. It also covers the visits to the station of the first Intercosmos crews. The scenes in space were shot by the cosmonauts.

21 *Novosti* reports that Soviet cosmonauts are to be provided with a small electron beam welding gun as standard equipment on all Soviet spaceships. This "will greatly simplify any necessary welding operations on the outside of spacecraft and space stations . . ."

21 Reported in Washington that an anti-satellite weapon based on a modified SRAM (Short Range Attack Missile) is being tested by the US Air Force. The missile, launched from an F-15 carrier aircraft in a high-speed "zoom climb" at about 80,000 ft 24 384 m) altitude, will 'pepper' its satellite target with a non-explosive warhead.

22 Reported that US Air Force is to establish a Consolidated Space Operations Center (CSOC) at Colorado Springs. To be completed by 1985, the $100 million facility will direct military Space Shuttle operations, control satellites and direct anti-satellite operations.

22 NASA announces that the Landsat 2 spacecraft has been retired from operation after five years of systematically studying the Earth's resources and environment because of wear-induced failure of its primary flight control mechanism. Engineers have placed the spacecraft in an engineering test mode for continuing evaluation of the attitude control problem. A two-month effort to keep the spacecraft pointed toward the Earth using other onboard flight assisting devices has so far proved unsuccessful. Landsat 3, launched in March 1978, will continue to provide data required by more than 400 domestic and foreign Earth resources programmes, says the report.

MAY ISSUE

The next issue of *Spaceflight* will include the following main features: 'Poland in the Intercosmos Programme' by Olgierd Wolczek; 'SRC Reviews Its Budget'; 'Hermann Oberth — 85 years: A Life for Spaceflight' and the 'Hermann Oberth Museum'; 'Soviet Re-entry Tests: A Winged Vehicle?' by Trevor Williams, and 'Burner 2 — Boeing's Small Upper Stage' by Andrew Wilson.

THE MANNED ORBITING LABORATORY PART 1

By Curtis Peebles

Introduction
1965 was a milestone year in the US space programme. It would see the first flights of the Gemini programme which would give the US the first orbital manoeuvring, the record for both total time in space and long duration flights and the first rendezvous. It would usher in the end of Soviet space preeminence. Even more so was the year 1969.

The components of Apollo were proven; leading to one summer day when mankind, unified in a single experience, watched as two men walked on the surface of another world. These two special years marked the start and the end of one of the least known space projects of the 1960's. This is the story of that project; the Air Force's Manned Orbiting Laboratory.

LOOKING FOR A MISSION
Since the mid-1950's, the Air Force had been seeking a manned spaceflight programme. Shortly before NASA was founded, the Air Force developed a step-by-step programme leading to a manned lunar landing[1].

In the wake of Sputnik, the Air Force was assigned a mission to develop the Dyna-Soar; a small one-manned winged spacecraft that could manoeuvre during re-entry and land like an aeroplane. But the project seemed unable to get started properly and underwent constant re-orientations. It suffered several changes of launch vehicles. The flight profile was changed from short sub-orbital flights to higher sub-orbital speeds and finally to orbital flights. Its purpose went from prototype of an operational system to purely experimental. All of these changes meant delay, and delay was becoming the story of the Dyna-Soar. But this was not its only problem; the Secretary of Defense in the Kennedy Administration, Robert S. McNamara, was hostile to the Dyna-Soar. He believed it was premature to develop an operational system. As an experiment, with a price tag of over $1,000 million, it failed the cost/performance analysis that was the hallmark of his administration. Sealing its fate, however, was NASA's Gemini programme. It could handle missions (such as rendezvous) that would require major modifications of the Dyna-Soar. So by 1963, few if any, had any confidence in the Dyna-Soar's ultimate success.

The Air Force sought a partnership in the Gemini programme, hopefully to develop into a separate Air Force programme called the "Blue Gemini". Although this would remain only a concept, it would lead to a far more ambitious programme.

On 10 December 1963, McNamara announced the cancellation of the Dyna-Soar. He had wanted it cancelled for a year but the controversies over the cancellation of the Skybolt and the awarding of the TFX contract (F-111) had delayed it. Also, NASA Administrator, James Webb, had been cool to flying military experiments on Gemini[2].

To replace Dyna-Soar, the Air Force was authorized to study its separate Gemini programme, the Manned Orbiting Laboratory (MOL*) The vehicle was a modified Gemini spacecraft attached to a cylindrical lab and launched by a Titan IIIC as one unit. Mission length was 2 to 4 weeks.

In the spring of 1964, the Air Force began to work on three main areas: to define what MOL is and what it will do; define the changes in the Gemini B spacecraft and define the mutual interest areas in the Gemini B, Titan IIIC, and lab[3]. The pacing item was the experiments since these would determine the hardware demands[4].

When McNamara announced the go-ahead for the MOL studies, he ordered the Air Force to justify the programme with a firm military mission. The Air Force found that too little was known about space travel to show what operational systems could do (total US manned space time was 54 hours). There were suggestions such as Cooper's ability to see houses, trucks, ships and other small objects from orbit[5].

So MOL was justified as an experimental programme to test man's military usefulness and his reaction to prolonged space flight. At this point, MOL was still on the ground floor. It still had to be "sold" to McNamara. The Air Force was put in the difficult position of having to prove that man was useful in space before it would be permitted to test man's usefulness in space. The Air Force shelved more ambitious space plans to concentrate on MOL and to harden it against the coming attacks of the office of system analysis, derogatorily known as the "Whiz Kids"[6].

However, paper studies were not the only activities in 1964; various design questions were, also, addressed. In particular, the method of transfer between the Gemini, in which the crew would be launched, and the lab. The leading contender was a hatch cut into the heat shield of the Gemini but there was concern over the structural effects. Other methods were EVA, an inflatable pressurized tunnel from the Gemini hatch back to the lab and rotating the entire Gemini back to form a direct link. The last two were used on NASA study vehicles[7, 8].

Tests were made on an oxygen/nitrogen atmosphere for the lab. It was known that pure oxygen had a detrimental effect when breathed for extended periods of time.

Launch of the MOL heat shield test, 3 November 1966. This was the only test flight of the MOL project that was completed. The schedule envisioned two fullscale unmanned MOL flights before the five manned missions.

USAF Photo

* *Pronounced Mole.*

In February 1964, Douglas, Martin Marietta and General Electric were awarded MOL study contracts. In May, small contracts were awarded to study various aspects of MOL. Martin looked into the role of the Titan IIIC; Hamilton Standard and Garrett Corporation studied the life support system. On 24 July McDonnell Aircraft was awarded a $1,189,500 fixed price contract for studies of Gemini B[9].

When various contractors expressed irritation at the slow pace, "Pentagon insiders" told them not to expect any speed-up until after the November Presidential election because of the Administration's desire to project an economic image[10].

The MOL, also, had a competitor — NASA's Apollo X* – a larger, more capable system to fly a wide variety of scientific and medical experiments for long duration Earth orbit missions. MOL appeared to duplicate its function. This resulted in a partial re-orienting of MOL. Although it was still to be a test project, it was to undertake work more in line with an operational system.

Two experiments were added to the project. These experiments, P-14 and P-15, were to be central to the MOL's mission. P-14 was the in-orbit assembly of a large high resolution radar antenna. P-15 dealt with a large orbital optical system[11].

As 1964 ended, it seemed certain that some type of manned military space programme would be funded. What type, what kind of hardware it would use and its scope were uncertain[12].

McNamara permitted the Air Force to begin work on MOL with the understanding that the hardware decisions were not to be made for several months yet[13].

In January 1965, the White House ordered detailed reports from both NASA and the Air Force on their respective space station programmes. These reports were to aid President Johnson and his advisers in deciding the path to take. There were basically three options; a go-ahead for MOL, joining MOL and Apollo X or cancelling MOL. The Air Force justified MOL on the basis that it could perform specific military experiments, NASA could not. NASA agreed, believing the projects were too divergent for a combined effort and that MOL would not answer the basic questions about long term space flight that Apollo X was designed for. Also, in January, the Air Force issued requests for proposals from industry and asked that they reply by 15 February.

In March 1965, Boeing, Douglas, GE and Lockheed were awarded $400,000 study contracts. The reports were due in May. North American was eliminated[14]. The decision on whether MOL or Apollo hardware would be used was not expected before late May or June[15].

May 13/14, the four possible contractors briefed the selection board on their respective proposals. They were given an extension to June 1st to complete their studies and submit them[16].

The summer of 1965 was to be the time of decision. The Air Force had grown weary of the 18 months of paper battles. Congress was beginning to support the project. On 3 June, the House Military Operations Subcommittee urged the Department of Defense to start MOL. Two weeks later, Representative John W. Wydler (R/New York) urged a speed-up of MOL and a major emphasis on military missions[17].

A meeting of the National Aeronautics and Space Council was scheduled for 1 July to develop recommendations. This meeting was later postponed to 9 July. McNamara and Webb attended; both stressed the two programmes were not duplications. This meeting resulted in one last delay. DoD had not briefed the State Department on MOL. State was now expressing concern over possible international implications of a manned military spacecraft. A decision was now not expected before mid-August[18].

On 25 August 1965, President Lyndon B. Johnson announced the formal go-ahead. Douglas was to build the laboratory, McDonnell was to build the Gemini B and GE was to manage the experiments. The vehicle would be 54 ft (16.8 metres) long in total. The laboratory, itself, was 41 feet (12.8 metres) long. It would weigh 25,000 lb (11,364 kg) Of this total, 5,000 to 6,000 lb (2,272 to 2,727 kg) would be the Gemini B. This was less than a NASA Gemini because most of the life-support and consumables were aboard the lab; 5,000 lb (2,272 kg) was reconnaissance equipment. This was less than the payload of unmanned reconnaissance satellites being launched at the time. Because of the human crew, much of the automatic equipment aboard such satellites, could be dispensed with. Unmanned flights would start in late 1967/early 1968. Manned flights would begin in late 1968/early 1969. Total cost was set at 1.5 billion. Launch vehicle was the Titan IIIC [19,20,21].

Development

The Air Force could now begin the Phase I contract definition. This continued into the fall of 1966. The Air Force began to refine the avionics equipment requirements. On 12 November 1965, the first eight MOL astronauts were selected: Major Michael J. Adams (AF), Major Albert H. Crews, Jr. (AF), Lt. John L. Finley (USN), Captain Richard E. Lawyer (AF), Captain Lachlan Macleay (AF), Captain F. Gregory Neubeck (AF), Captain James M. Taylor (AF) and Lt. Richard H. Truly (USN). Major Crews had been picked to fly the Dyna-Soar before it had been cancelled.

As the Air Force continued the Phase I development, the avionics requirements were proving more difficult than expected; resulting in a weight gain. Total weight was now over 30,000 lb. (13,636 kg) requiring a new booster. The Air Force finally settled on the Titan IIIM. The major change was the use of 7-segment solid fuel strap-on boosters rather than the 5-segment boosters of the Titan IIIC. The first stage engines used a new 15 to 1 expansion nozzle; lift-off thrust was 3 million lb (1,363,636 kg); there was no trans-stage[22]. Tests on the design continued. In March 1966, the transfer tunnel was tested at the Arnold Research Development Center[23].

Despite the problems, support was strong. For 1966 (fiscal year 1967), $150 million was budgeted. Congress added $50 million to this. Later, to accelerate the programme, DoD re-programmed an additional $28.4 million. The programme seemed well on its way. On 29 April 1966, McDonnell received a $2,071,882 contract for Gemini B heat shield work.

They were, also, re-conditioning the Gemini 2 spacecraft. It had been flown in an unmanned ballistic test in January 1965. It would be re-flown on a Titan IIIC to test the integrity of the hatch. It would be attached to an experiment canister built from a Titan II first stage. At 34 ft long (10.6 metres), it was shorter than the real MOL. In fact, there was almost no real MOL hardware aboard either vehicle except the hatch. Later, according to the schedule, two full orbital unmanned tests of the MOL would be made followed by five manned 30-day flights.

In June, a second group, of MOL astronauts, was announced: Captain Karol J. Bobko, Captain Charles C. Fullerton, Captain Henry W. Hartsfield (all Air Force) Lt. Robert L. Crippen (Navy) and Captain Robert F. Overmyer (USMC).

In July, Adams left MOL programme for the X-15 project. He was replacing Captain Joe Engle who was selected as a NASA astronaut.

In September, the MOL project office was negotiating the Phase 2 hardware development contracts with the prime contractors. This marked the end of the Phase I (project definition)[24].

This phase had seen the first slippage; the first manned flight had slipped later into 1969. The heat shield qualification flight, originally scheduled for October 28, 1966, was not launched until 3 November. The sixth research and development Titan IIIC was fired out of Cape Kennedy. When the equipment canister and attached Gemini 2 reached 125 miles

* *Later designated Apollo Application Project and still later, Skylab.*

First group of MOL astronauts: September 1965. *Left to right*, Major Michael J. Adams, Major Albert H. Crews, Jr., Navy Lt. John L. Finley, Capt. Richard E. Lawyer, Capt. Lachlan MacLeay, Capt. F. Gregory Neubeck, Capt. James M. Taylor and Navy Lt. Richard H. Truly.

USAF Photo

Second group of MOL astronauts selected June 1966. *Left to right*, Navy Lt. Robert L. Crippen, Marine Capt. Robert F. Overmyer, Capt. Karol J. Bobko, Capt. Charles G. Fullerton and Capt. Henry W. Hartsfield, Jr. All were subsequently transferred to NASA.

USAF Photo

(201 km), the transtage pitched down and the Gemini was released. It flew a maximum lift/drag re-entry profile for a maximum heat load. Speed was 17,500 mph (28,225 kph.). It flew a 5,500 mile (8871 km) trajectory and landed only 7 miles (11.3 km) from the recovery ship, *USS LaSalla*.

After the Gemini separated, the transtage and canister pitched up and boosted itself into orbit. The transtage restarted twice to place itself into a 184 by 183 miles (296 by 295 km) circular orbit.

Three satellites ejected from the canister. Two were the OV 4-1R and OV 4-1T comsats. They tested satellite-to-satellite communications using the atmospheric F layer as a wave guide. The other satellite, OV-1-6, had a classified purpose but it may have been an inflatable decoy.

The canister carried 9 on-board experiments: the Biocell experiment which provided data on cell growth in Zero-g; ORBIS (orbital radio beacon ionosphere satellite) whose purpose was to determine if a transmitter could use the ionosphere to reach distant stations; a zero gravity propellant gauging system which used sound waves to measure propellant; a set

Third group of MOL astronauts selected June 1967. *Left to right*, Lt.-Col. Robert T. Herres, Major Robert H. Lawrence, Jr., Major Donald H. Peterson and Major James A. Abrahamson.

USAF Photo

of corner reflectors which were used in conjunction with a laser experiment at Cloudcroft, New Mexico; a micro-meteoroid detector; a heat transfer experiment; measurements of aerodynamic heating on an exposed attitude control system (this had a direct bearing on MOL); a pattern of stripes from 5.7 to 50.9 inches (14.5 to 129.3 cm) wide were painted on the side of the canister (they were photographed by a telescope at Cloudcroft, New Mexico) and an orbital fuel cell test.

In addition to these nine experiments, the launch stresses on the long booster shape provided data on the structural requirements of the MOL/Titan IIIM[25].

Post flight analysis of the Gemini showed the hatch system had not degraded the heat shield's effectiveness or structure. As expected, the hatch had welded shut.

A Casualty of War

The avionics problems that beset the Air Force had caused a major slippage. The first manned flight had slipped from the announced schedule of late 1968/early 1969 to late 1969/early 1970. The cost had, also, increased to $2,200 million. To keep the programme, more or less on schedule, the Air Force had requested $510 million. DoD cut this to $480 million. The reason for MOL's abrupt reversal in financial fortunes was the increasing cost of the Vietnam War. Steadily more and more of DoD's funding, ever increasing numbers of aircraft, troops, ships and support were being committed. Funding was being siphoned off from other projects not directly involved. As the war increased, the budget was again cut to $430 million. Later, if the development problems were solved, money could be reprogrammed except there was no money to be spared[26].

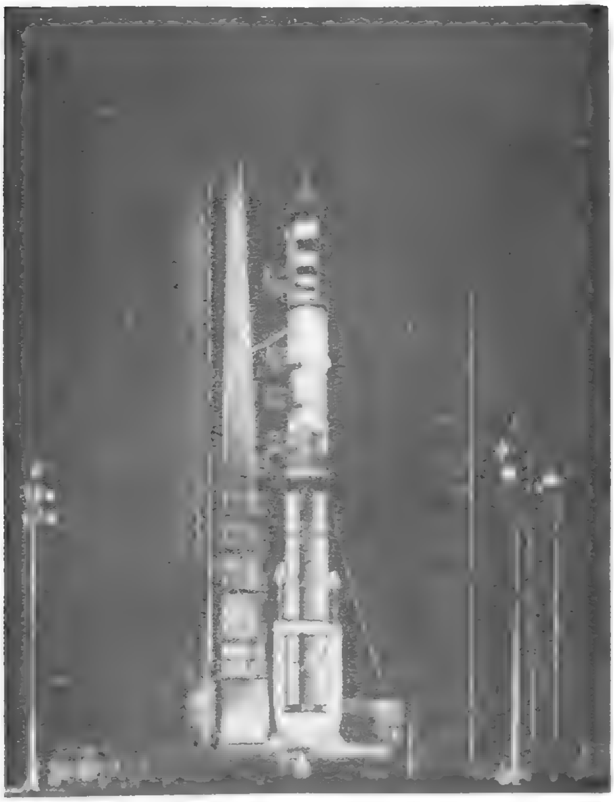
On 19 May, two fixed price MOL contracts were issued. Douglas Aircraft received a $674,703,744 contract for the lab. McDonnell received a $180,469,000 contract for the Gemini B. Before the year was out, the two firms will have merged. On 29 May, GE received a contract for the experiment-integration work on MOL[27].

Despite the funding cuts and development problems, the remaining questions about the technical features of MOL had been settled. After the MOL was orbited, the crew would open the 26 in (66 cm) diameter hatch and move through the transfer tunnel into the lab. The lab was 10 ft in diameter and 14 ft long (3.13 by 4.38 metres) and was divided into two sections. The interior volume was approximately 1,100 ft³ (33.5 metres³). The atmosphere was 31% helium, 69% oxygen at 5 psi (.35 kg/cm). The Gemini B used 100% oxygen. The atmosphere was selected for medical and fire reasons. A 30-day oxygen/helium chamber test was made in the spring of '66[28].

The life support system used a molecular sieve which replaced the lithium hydroxide canister of Mercury and Gemini. After activation of the life-support system, the crew would remove their space suits and begin their 30-day mission. There were 25 basic experiments; 15 primary, 10 secondary. The primary experiments were: large optics in space, the assembly, erection and alignment of large structures in space; tracking of ground and space targets and spotting targets of opportunity, electromagnetic intelligence surveys, multi-spectral photos, in-space maintenance, post-strike target assessments, EVA tests with an astronaut manoeuvring unit, autonomous navigation, biological and medical experiments, ocean surveillance and general performance in the military area[29].

The presence of man on the scene meant the application of human decision-making processes to orbital reconnaissance. The astronauts could spot new targets with binoculars and immediately photograph them with the on-board equipment. Previous to this, two different types of satellites and several months would be necessary for such coverage. Also, electromagnetic intelligence could be speeded up. A radar signal could be checked by the crew to determine if it was a new site or a new type. The crew could then pick the best equipment for analysis[30].

The accumulated film and tape would periodically be returned using separate re-entry capsules. Because the MOL would pass over all the Earth's oceans, the crew could spot, classify and track shipping. Navy space enthusiasts pushed for an all navy MOL. They hoped the fourth manned MOL would carry a navy crew and be equipped solely for ocean surveillance and anti-submarine warfare[31].



Pre-dawn preparations of the Titan IIIC. In addition to the re-conditioned Gemini 2, the canister, also, carried three sub-satellites and nine on-board experiments.

USAF Photo

The secondary experiments were material degradation, multi-spectral analysis of the planets, recovery of space objects, airglow photography and analysis, electron-density, plasma, communications propagation, ultra-violet photos and passive propellant settling systems.

Behind the lab was the unpressurized equipment module. It was 35 to 37 ft long (10.9 to 11.5 metres) and was the location of the engineering systems, attitude control fuel, tanks for the liquefied gases for breathing and fuel cell operations. It was accessible to space suited astronauts for adjustment and repair.

Communications to the satellite control facility was through the Air Force's own ground stations. This avoided possible international problems over the use of NASA stations for control of the military MOL. The orbit would be higher than the standard Gemini; possibly as high as a 300 mile (483 km) circular orbit and inclined 85° to 92°[32].

After completing its mission, the crew would return to the Gemini B, power it up and separate from the lab. The Gemini B could operate as an independent spacecraft. It had a loiter time of 14 hours. The mission would be completed with splashdown in one of the two recovery zones or in a smaller secondary zone. The laboratory would be left to burn up on re-entry. Medical and scientific information would be shared with NASA.

In late 1964, an agreement was reached between the Air Force and NASA covering information exchange. In November 1965, NASA was authorized to transfer excess equipment to the MOL project. Soon afterwards, several boiler plate test vehicles and support and handling equipment were transferred and MOL officers and astronauts were briefed on the Gemini programme.

In March 1967, NASA transferred the Gemini 6 spacecraft to the Air Force as a training aid for MOL crews[33].

Disposal

Few artifacts of the MOL programme still exist. The twice-flown Gemini 2, used for the heat shield test, is on display at the Kennedy Space Center. All of the satellites orbited in that launch have subsequently decayed. The canister re-entered on 9 January 1967. The OV4-1-R re-entered on 5 January 1967. The OV4-1-T re-entered on 11 January 1967 and the OV1-6 on 31 December 1966.

The MOL 1 capsule (alias Gemini 3A) is on display at the Air Force Museum, Dayton, Ohio. It originally was a static test article that was modified for altitude chamber tests and subsequently brought up to full manned-rated status[47]. The San Diego Aerospace Museum has, in its possession, a 1/30th scale model of the final MOL configuration.

On 30 June 1967, the third and last MOL crew selection was made. Of 16 candidates, (all Air Force) 4 were selected: Major James A. Abrahamson, Lt. Col. Robert T. Herres, Major Donald H. Peterson and Major Robert H. Lawrence, Jr. Major Lawrence was the first black selected for astronaut training. In addition to being a graduate of the Aerospace Research Pilot's School, Lawrence had a PhD in nuclear chemistry from Ohio State University. At the press conference, he called his selection "just one of the things we look forward to in the normal progression of civil rights in this country"[34].

Development work undertaken in 1967 included the completion of the engineering mock-ups, the start of work on the launch pad and support facilities, fabrication of the first flight MOL components and the testing of the Titan IIIM first stage[35].

On 8 December, Major Lawrence was killed in an F-104 landing accident. Injured in the crash was Major Harvey J. Royer, chief of operations at ARPS[36].

The Long Decline

The war in Vietnam had continued, ever expanding, and to MOL's supreme misfortune, 1968 was, also, the programme's peak funding year. The Air Force requested $630 million; this was marginally sufficient to keep MOL on schedule. Work to be undertaken was the major portion of the structural test programme on flight hardware, continued fabrication of the first three flight MOLs (the first two unmanned test vehicles and the first manned vehicle), development of the solid fuel boosters and installation of ground equipment in SLC-6 launch pad[37]. The Air Force was not optimistic about getting the full amount. Whenever military funding becomes tight, traditionally, the first thing cut was military research and development funds.

In 1968, long range aerospace research programmes were being postponed or cancelled as every possible source of funding to support Vietnam war costs was sought out. The Air Force expected the cut in MOL's budget to possibly be as high as $100 million. If so, the project could possibly slip into 1972[38].

Ultimately, the Congress directed an $85 million cut; less than feared, but still sufficient to cause the first manned mission to be delayed into 1971. There was, however, some good news for MOL – the last of the technical problems had been overcome by mid-'68. One problem was the stability of the MOL during photo sessions. The long focal length of the optics would magnify the effects of any vibration which would degrade photo resolution[39].

Other events during the year – the MOL astronauts had begun their preliminary training. In the spring of '68, several of them used a mock-up of the transfer tunnel during zero-g flights of a KC-135. Later that year, Hamilton Standard developed a more flexible version of the MOL space suit. Both NASA and the Air Force expressed interest[40]. One effect of the development problems was the cancellation of the Pratt-

Whitney fuel cell. It was replaced by a higher capacity Allis Chalmers Manufacturing Co. capillary fuel cell. The increased power demands of MOL had out-stripped the Pratt-Whitney system[41].

The End of MOL

In January 1969, Richard Nixon became President. For a time MOL's fortunes seemed to improve. The out-going Johnson Administration's budget, for fiscal year 1970, had included a total of $576 million for MOL – a level of funding which ended the deferment of the McNamara years.

Activities would include thermal and dynamics testing of major components, delivery of the first flight MOLs. The start of construction of later MOLs, activation of the launch pad, beginning pilot training and delivery of booster components for assembly[42].

The new Air Force Secretary, Dr. Robert C. Seamans, was a strong supporter of military space missions and in hearings he called MOL "important, even urgent"[43].

The new Secretary of Defense, Melvin R. Laird, had been conducting a review. He found that the budget's analysis of the Vietnam situation was too optimistic. Costs would continue at present levels for at least two years. Also, there were undisclosed cost increases in several projects. The fiscal conditions of the previous years were continuing and it was necessary to make cuts. MOL's share was $20 million. This was accomplished by eliminating the last manned mission. Faced with the necessity of making cuts, Seamans agreed that this would be the least damaging alternative. It was justified as improvements in avionics allowed the goals of the first five manned flights to be accomplished in four. The Air Force was given an option – if funding problems had eased, the Air Force could request money for the fifth mission in 1971. At that time, the production lines would still be open[44]. The funding crunch was proving to be more serious than earlier believed. A further $31 million was cut. This pushed the launch date back again. The first unmanned launch was early 1971, first manned mid-1972.

For the first time, the spectre of programme cancellation had been raised. There was, also, a move against MOL in Congress. It was one of 15 defence projects whose elimination was sought by a group lead by Senator Mike Mansfield (D/Montana)[45]. The total cost had escalated to $3,000 million both due to inflation and the delays. In the four years since the programme began, space technology had advanced. Many of the things MOL was to do could now be accomplished by unmanned reconnaissance satellites. Although not having the flexibility of a human crew, they could provide operational systems as opposed to the limited test project MOL represented.

On 10 June 1969, Secretary of Defense Laird reluctantly cancelled MOL. The reasons given were the need to reduce defence spending and advances in unmanned space systems. The move caught the Air Force and the contractors by surprise. Termination costs were estimated to be $75 million and saved $1.5 billion over the next four years. Approximately 10,000 people were either laid off or transferred[46]. Seven of the astronauts were transferred to NASA. Also, transferred was the MOL food and diet contracts and the space suit development. The nearly completed SLC-6 pad was placed on a stand-by status. It took four satellites to replace MOL: the Big Bird Reconnaissance satellite, the Titan IIIB launch area surveillance satellite, the Navy's Whitecloud ocean surveillance satellite and the Air Force's weather satellite. They provide vital data on the military situation facing the US, which, in the final analysis, is what really matters.

Conclusions

There is little question about the reasons for MOL's failure. It was acute financial starvation; it was simply never given enough money for the programme to develop so it was delayed to the point of technical obsolescence. The changes in system configuration and technical problems were secondary. Each programme, no matter how intriguing or useful, must stand on its own. It must have the capacity to change with the times, adapting to the new circumstances it finds itself in.

The failure of MOL meant the loss of 300 man days in space. The experiments in space assembly, in-flight repairs, medical and EVA would have benefitted Skylab. Since the MOL would have made several 30-day flights, there would have been no need to limit the first Skylab mission to 28 days. But such speculations are unproductive since history does not give its alternatives. It does, however, provide comparisons. The histories of Apollo and MOL are most instructive. Apollo was begun with an unmistakable call to arms; MOL began with an authorization to study a mission. The method of reaching the Moon was decided after authorization was received. Hardware requirements for MOL were studied endlessly before go-ahead was given – losing 18 months of development time. Apollo kept its high level support in both the good times and the very bad. MOL kept its support only briefly before events pushed it aside. And most importantly, Apollo was a programme that advanced the limits of space technology and human experience. It had an unmistakable goal and was pressed toward that goal with energy, vigour and determination. MOL was a very limited test exercise pressed with no particular emphasis. Apollo succeeded, MOL did not.

To be continued

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SYLDA FOR ARIANE

During the early 1980s, a number of payloads in the 600 to 1000 kg class are due for launch into geostationary transfer orbit. This type of payload would normally be orbited by a US Delta vehicle or as part of a Shuttle payload.

The carrying capacity of Europe's launch vehicle, Ariane, is about 1700 kg, which would allow it to carry two such satellites. To capitalise on this, the European Space Agency has awarded a contract for the construction of SYLDA (*Sys*teme de *L*ancement *D*ouble *A*riane) to Aerospatiale, writes Robert D. Christy.

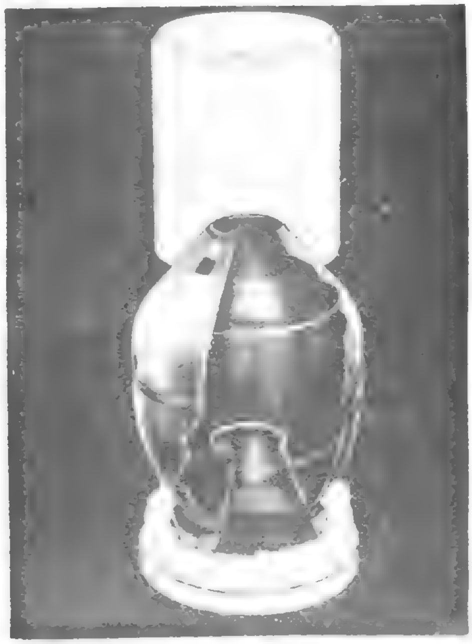
SYLDA is being built at the Les Mureaux Centre of Aerospatiale. The programme was initiated in June 1978 and the first use of SYLDA will be during 1980 on Ariane launch L-04 (the fourth trial launch).

The problems to be solved by engineers were to build a structure capable of supporting two satellites, making such a structure fit within the standard Ariane launch shroud, keeping mass to a minimum and ensuring that the satellites could be totally independent of each other. All these requirements were met by developing a container for the lower satellite which also acts as a support for the upper one.

SYLDA is a two part structure designed to split in an equatorial plane, after separation of the upper satellite. The lower vehicle is then free to depart on its own trajectory. Careful choice of separation velocities for the two satellites and the upper part of SYLDA ensures that there is no danger of collision between them.

Although SYLDA's mass is 165 kg, the total weight penalty is only 120 kg because it replaces the normal Ariane separation system. Its structure is a honeycomb aluminium core covered in layers of carbon fibre. Windows in its lower section allow access to the enclosed satellite and also permit two-way radio communication. The two halves are held together by conventional clamping bands which are released by pyrotechnic devices. Four springs ensure separation.

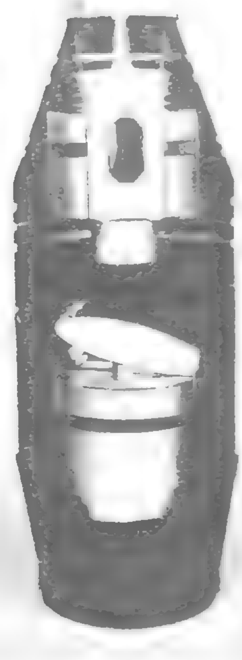
The shape of the device imposes some constraints on the shape of the lower satellite. Otherwise, the upper limits are 2.6 m in length and 2.2 m diameter. The combined masses of the satellites should not exceed 1580 kg at present. Mechanical and electrical interfaces with the satellites are identical to those of the Shuttle Payload Assist Module, and the volume offered to the upper vehicle is the same as that of the PAM. Later development plans include expansion of the structure by a further 0.5 m on its length which will mean that two PAM-sized satellites can be carried. This would depend on expanding the standard Ariane shroud and uprating the launch capacity to 2300 kg.

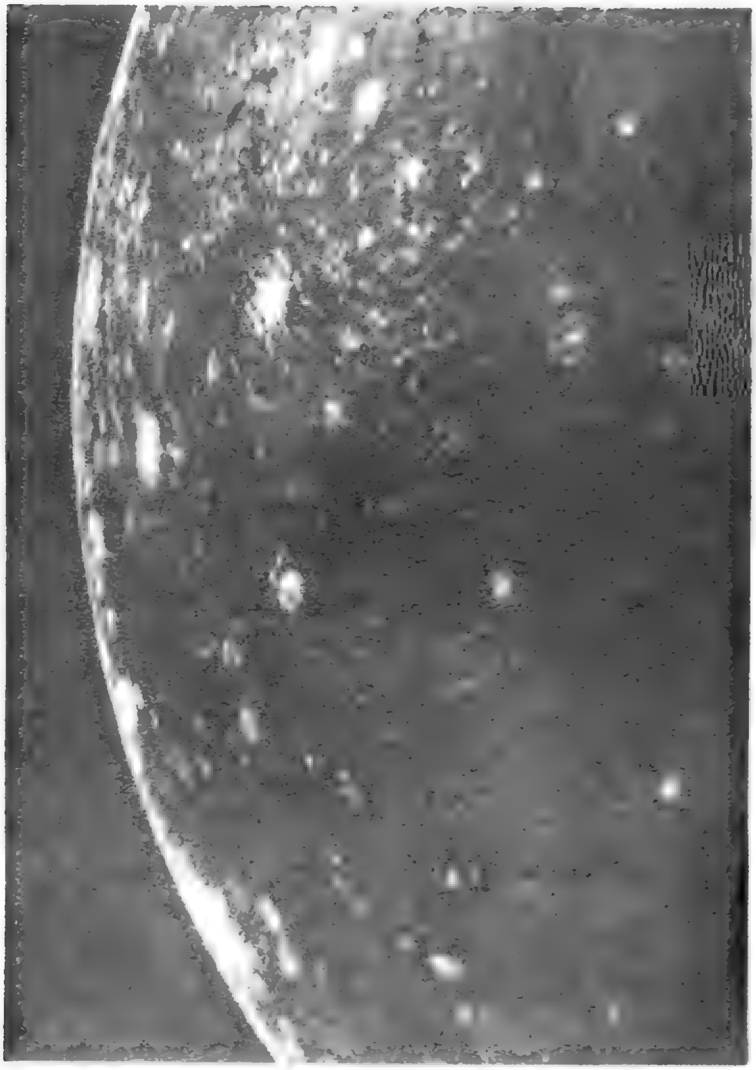


Above, artist's impression of SYLDA.

Below, SYLDA components under construction at Les Mureaux. *Right*, Ariane launch vehicle, shroud, showing satellite configuration using SYLDA. The upper satellite is a Meteosat, the lower one Sonate.

All illustrations Aerospatiale

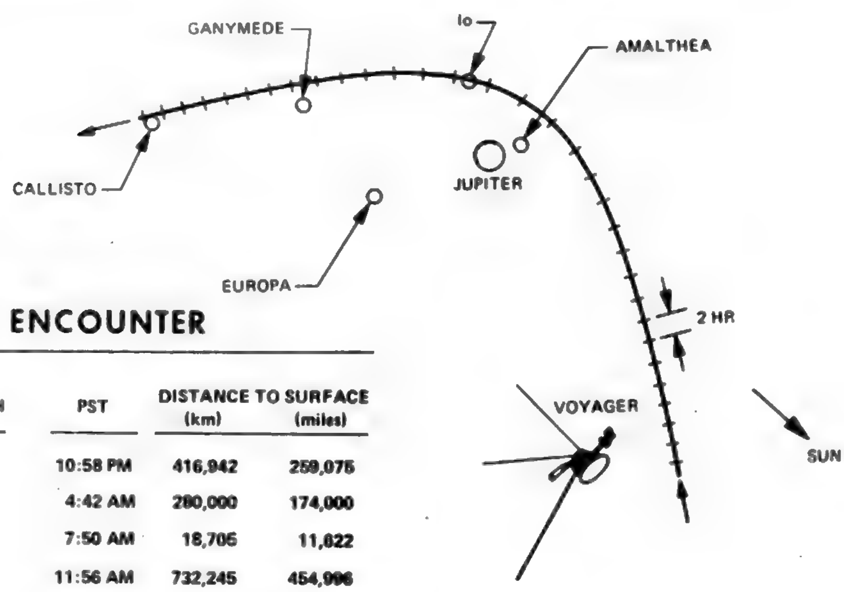




MOONS OF JUPITER–CALLISTO

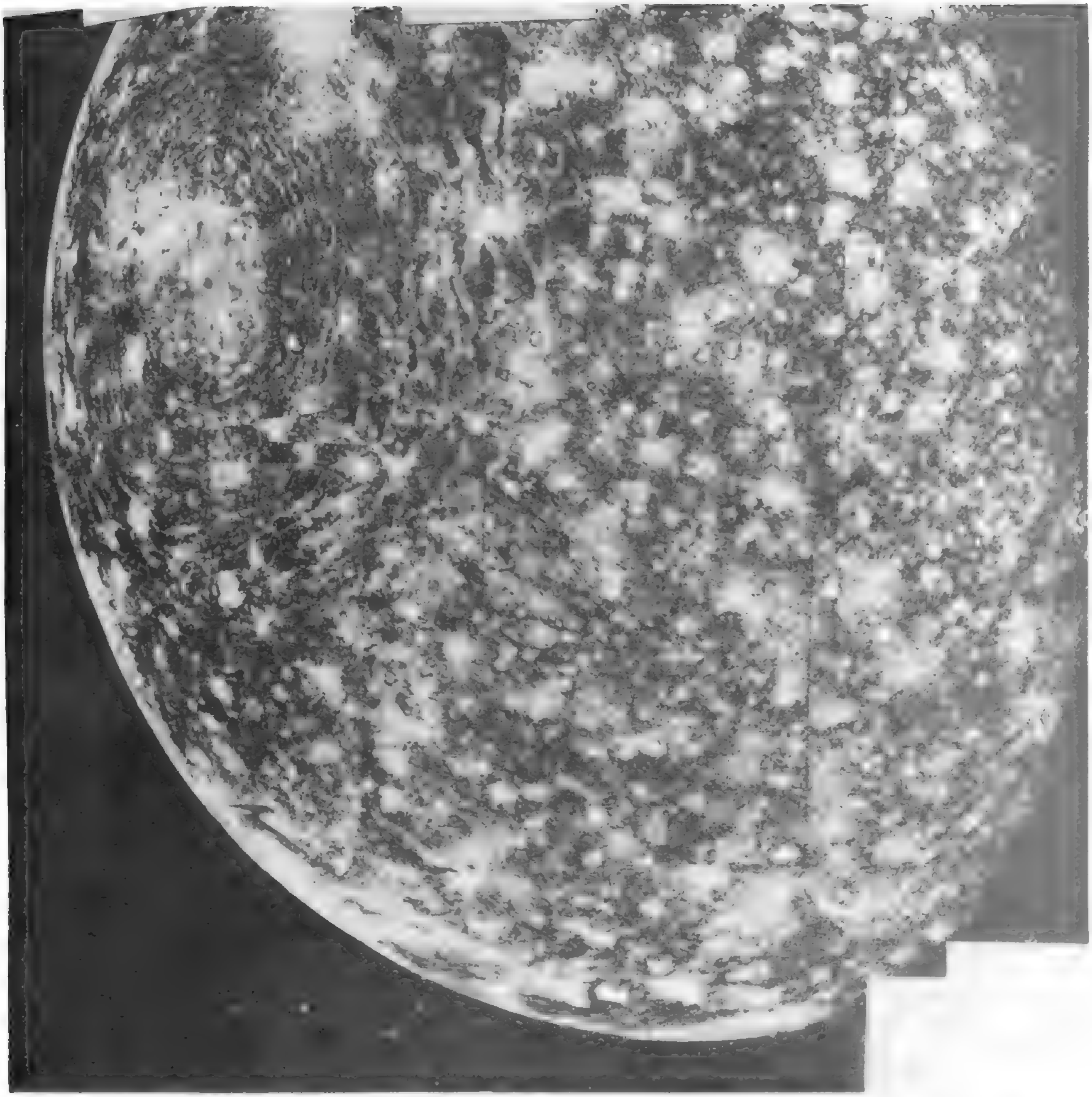
In this second part of our close-up feature on the Jovian satellites we focus on Callisto. The photographs were taken by Voyager 1 during the flyby on 6 March 1979. *Left*, this picture was taken when the spacecraft was 350,000 km from the moon and the camera shows features on its surface about 7 km across. Callisto is a little smaller than Ganymede (about half the size of the planet Mercury) and is apparently composed of a mixture of ice and rock. The darker colour of Callisto – about half as reflective as Ganymede but still twice as bright as our Moon – suggests that the upper surface is "dirty ice" or water-rich rock frozen on Callisto's cold surface (approximately −243° F or 120 K at the equator). As can be seen in the picture on the facing page, far more craters appear on the surface of Callisto than on the surface of Ganymede, leading scientists to believe that Callisto is the oldest of the Galilean satellites perhaps dating from the final accretional stages of planet formation 4,000 to 4,500 million years ago.

We gratefully acknowledge the cooperation of the Jet Propulsion Laboratory, Pasadena, in presenting this feature. An illustrated review of Ganymede appeared in our February issue



VOYAGER 1 ENCOUNTER

	CLOSEST APPROACH	PST	DISTANCE TO SURFACE (km)	DISTANCE TO SURFACE (miles)
AMALTHEA	1979 MARCH 4	10:58 PM	416,942	259,076
PLANET JUPITER	1979 MARCH 5	4:42 AM	280,000	174,000
Io	1979 MARCH 5	7:50 AM	18,705	11,622
EUROPA	1979 MARCH 5	11:56 AM	732,245	454,996
GANYMEDE	1979 MARCH 5	6:53 PM	112,036	69,616
CALLISTO	1979 MARCH 6	9:46 AM	123,663	76,840



The prominent bullseye feature is believed to be a large impact basin, similar to *Mare Oriental* on the Moon and Caloris Basin on Mercury. The bright circular spot is about 600 km across. The outer ring is about 2600 km across. This is the first recognised basin in the Jovian system and supports the concept of an ancient surface. The lack of high ridges, ring mountains, or a large central depression suggests that the impacting body may have come close to penetrating Callisto's crust. The differences in the appearance of this basin compared with those of the inner solar system may result from the fracturing of Callisto's crust. The lack of obvious basins on the side of Ganymede observed by Voyager 1 and the smaller number of craters on Ganymede's surface suggest that Callisto may have a thicker crust than Ganymede.

NASA, Jet Propulsion Laboratory

Our next astro-feature will focus on Jupiter's newly-discovered ring and 14th moon. First hint that an apparent star-trace photographed by Voyager 2 was a Jovian satellite was revealed by two researchers at the California Institute of Technology. The moon orbits at the outer edge of the ring about 57,800 km from the cloud tops of the giant planet. It is estimated to be only 30 to 40 km in diameter, smaller than seven of Jupiter's other moons but larger than six.

NON-CORROSIVE LUNAR IRON

The discovery by Soviet scientists that the lunar regolith – the dust that covers the Moon's surface – contains non-oxidized iron has been registered at the Soviet Committee for Inventions and Discoveries. The samples proved to be corrosion-resistant when exposed to the terrestrial atmosphere as well. Later the discovery was confirmed at other Soviet and American laboratories. Non-oxidized forms of silicon and titanium were also found in the regolith.

The formation of these unusual forms of elementary substances is connected with the action of the "solar wind" on the surface of the Moon, explains Dr. Valery Barsukov, director of the Institute of Geochemistry and Analytical Chemistry. It is this "wind" – a flux of high-energy charged particles that falls on the Moon's surface unprotected by an atmosphere – that lead to the formation of unusual non-oxidized forms of elementary substances.

Protons and other particles of the "solar wind", Barsukov says, "seize the oxygen of the lunar matter and carry it away into space, leaving pure metals on the lunar surface. We expected to find on the Moon substances of a low degree of oxidation but the fact that the iron has not oxidized in the eight years since the Luna 16 expedition surpassed all expectations."

Barsukov points out that the discovery is not merely an important step in understanding the physical and chemical properties of planetary bodies; it has practical importance, too. By simulating the effect of the "solar wind" on metals in the laboratory it is possible to obtain anti-corrosion materials. In the Soviet Union industrial apparatus has already been development for the treatment of engineering components by just such methods.

EUROPEAN SPACELAB. Technicians install equipment on one of ESA's flight pallets. The pallets, with various experiments mounted on them, will be carried in the cargo bay of the Space Shuttle. This pallet will be flown on OFT-4. *NASA*

CLOSED ECOSYSTEM FOR SPACE

University of Florida researcher Gary Noyes is developing a method of recycling organic waste for possible use in a closed ecosystem for human life-support in space.

The closed ecosystem prototype is a sealed transportable half-cylindrical greenhouse which could support as many as ten crew members on a rotational basis. On either side of the half-cylinder is a sub-irrigated sand medium separated by a conduit that serves as an access walk. The prototype will eventually provide the crew with quarters of insulated sheet-metal. It will contain sleeping accommodation, a control room airlock, galley, and an analytical laboratory.

Air flows from the crew living quarters and life support facilities through an access duct into the crop products area, passing first over temperate crops and then over subtropical crops before exiting the greenhouse. Next the air enters a series of condensers which dissipate the accumulated heat and is again ready to repeat the cycle. The climatic gradient of the greenhouse permits a high crop diversity in a limited space.

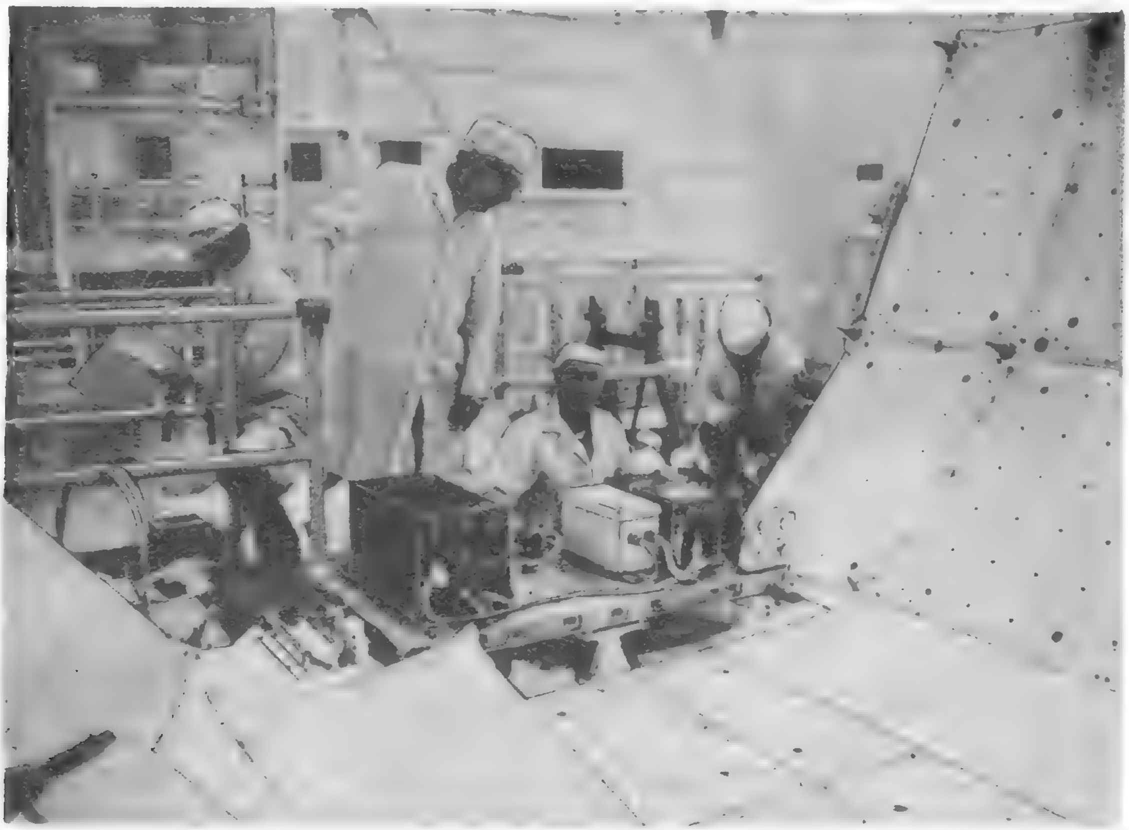
The waste from the products of the system would be burned in a closed, self-supporting environment in which nothing is wasted and everything is reused.

The ash and gaseous nitrogen and sulphur oxides are converted into liquid fertilizer for the hydroponically grown plants. These plants require no soil and grow much faster than plants grown in soil.

According to Noyes, "There are several ways of getting rid of waste by converting it into an acceptable environmental material. The problem with most methods, including compost, is that they are too slow. The slower a method is, the more space needed."

Noyes stated that the waste is first ground and dried, using heat from the incinerator already in operation. "If conditions in the incinerator are right, carbon dioxide, sulphur and nitrogen oxides are produced by the burning process."

These by-products are put through an absorber, where they are combined with hydrogen peroxide, which is easily made



in a closed ecosystem. An acid solution is produced which in turn combines with the residual ash to make a mineral salt fertilizer which is used on the plants. This completes the closed cycle.

While the system will not be 100 per cent closed the researchers are striving for as efficient a system as possible. "There will be a little bleed-off," Noyes explained, "but if you recycle 98 per cent of the waste it will be much easier to bring up 2 per cent of the food from Earth than to bring up the full 100 per cent."

Presently a five year evaluation is contemplated. For the first year organic wastes will be subjected to the waste treatment to produce crop nutrient solution. The following year the characteristics of the closed ecosystem will be tested. That year the crop production will be subjected to the waste treatment and the resultant nutrient solutions will be put back into crop production. The workings of the greenhouse for crop production and the incineration treatment of the waste will have been tested and verified.

In the next year the ecosystem testing will be extended to detailed design and cost-determination. Cycle evaluation will begin with the crop production being used for food by pigmy swine who serve as human surrogates. Some of the crop production will also be used for the waste treatment process to produce the nutrient solutions needed to support crop production.

The fourth year entails the addition of animal production to the system. The animals will be fed from the crop production and in turn provide food for the human surrogates.

The final year would culminate with the testing of the system with humans taking the place of their surrogates.

We wish to thank Gary Noyes, M.E., University of Florida, for the use of this material. Ed.

SPACE SHUTTLE PAYLOADS

Despite the delay in launching Columbia on its first test flight from Cape Canaveral, NASA has received firm payload commitments for the first 37 operational flights beginning in 1981. The Shuttle is thus almost completely booked to the Spring of 1984.

The 47 payloads supported by these flights represent commitments by 14 government, commercial and foreign users, and range from the European Space Agency's Spacelab to weather, communication and navigation satellites.

NASA payloads are expected to account for 32 per cent of these payloads, the Department of Defense about 15 per cent and all other users about 53 per cent.

These payloads normally are assigned to flights on a first come-first served basis. However, missions that involve national security will be given priority, as well as missions with significant scientific and technological objectives or time-critical launch windows. Flights for which NASA will be fully reimbursed also will be given preference over routine scientific and technological experiments.

A range of services are available to Shuttle users. Standard services, which are uniform for all non-government users, include a basic Shuttle launch for a one-day mission with a standard orbital altitude and inclination, three person crew and standard support services. Optional services are available at extra cost upon request. These services could include special hardware, analysis and testing, use of Kennedy Space Center facilities and services, and special orbital operations such as extra-vehicular activity and missions of longer duration.

In addition to the 47 large payloads that will occupy much or all of the Shuttle's cargo bay, more than 200 organizations and individuals have reserved room for some 300 small self-contained payloads, called Getaway Specials. These universities, companies and researchers, for $3,000 to $10,000, will send their own 200 lb or less payload into orbit aboard the Shuttle. These Getaway Specials must be of research and development nature.

The Shuttle's first payload, one of three preliminary payloads scheduled to fly before the Shuttle becomes operational, will ride the second orbital flight test scheduled this year. Named OSTA-1 for NASA's Office of Space and Terrestrial Applications, the payload will consist of six Earth-sensing experiments designed to enable scientists to pinpoint natural resources and to study air pollution, lightning and ways to locate and track surface features and clouds. The payload will include also a life sciences experiment designed as a prototype for an experiment to be flown aboard the Spacelab, the pressurized manned orbiting laboratory designed to fit in the payload bay.

The third orbital flight test will have a payload designed to allow astronauts to test the Shuttle's remote manipulator system. This is a mechanical arm that will be used to take payloads out of the cargo bay, position them in space and also to retrieve satellites for return to Earth.

On the final flight test, an Office of Space Science payload (OSS-1), concerned with physics and astronomy experiments, will be aboard.

LANDSAT 2 SHOWS ITS AGE

Landsat 2, the second in a series of Earth orbiting satellites used to monitor the world's resources from space, shows signs of wearing out after almost five years of continuous service. The spacecraft, with a designed life expectancy of only one year, has been experiencing difficulty in its onboard attitude control mechanism.

Controllers for the spacecraft at NASA's Goddard Space Flight Center believe that a rotating fly-wheel used to stabilize the spacecraft's yaw, or side-to-side motion, has become jammed due to degraded lubrication.

The controllers have succeeded, since the problem was discovered on 5 November 1979, in reorienting the spacecraft's solar panels toward the Sun. With the spacecraft's solar panels again pointed toward the Sun, power supplies are adequate for operations and the attitude can be maintained, thus allowing more time to free the jammed yaw control fly-wheel or attempt an alternative control procedure.

If Landsat 2 joins Landsat 1 (launched in 1972 and retired in 1977) in retirement, Landsat 3 will remain as the sole United States Earth resources monitoring satellite in orbit until Landsat D, the fourth and most advanced spacecraft in the series, is launched in late 1981. There was hope that Landsat 2, despite its age, could provide supplemental worldwide coverage to Landsat 3 until late 1980.

Landsat satellites weigh about 900 kg (1,200 lb) and orbit the Earth every 103 minutes, some 910 km (570 miles) in space. Their remote sensing instruments send back images of Earth in 185-km (115-mile) strips running nearly north-to-south at an angle to the equator of 99 degrees. In this type of orbit, surface coverage of the Earth proceeds westward, with a slight overlap, so that the globe is covered every 18 days.

Landsat data has been used by scientists and local officials in the United States and more than 100 foreign countries for a wide variety of applications ranging from crop inventories to flood assessment and mineral exploration.

In addition to the three Landsat monitoring stations in the United States, seven foreign Landsat ground stations operate throughout the world with several more under construction and a number of others in the planning stages. It is expected that these domestic and foreign ground stations will have the capability to receive, process, archive and disseminate Landsat 3 data on a global scale to partly offset the effect of the loss of Landsat 2.

NASA/DoD SPACE MARKET 1984

Spending by NASA and the Department of Defense on their space programmes is forecast at a cumulative $35.4 billion for FY1978-1984 in Frost & Sullivan's latest analysis, "U.S. NASA/DoD Space Market". Combined annual funding for both Government agencies is estimated to grow 46% during the period, from $3.9 billion* in FY1978 to $5.7 billion FY1984, with the latter year marking a high.

Among NASA programmes, Space Transportation Systems will account for slightly more than half of the total NASA budget in the seven years but annual budgeting will decline after FY1980, reflecting the maturing of the Space Shuttle programme. Space Sciences will show the greatest growth among the NASA group, doubling annual expenditures by FY1984.

DoD space funding will be dominated by Military Satellite Communications whose yearly outlays will expand by 75% over the span. Air Force Spacecraft Launch and Operations also will merit sizeable appropriations but Space Defence will be heavily accented, with annual funding escalating 516% during FY1978-1984.

NASA will allocate $11.1 billion to Space Transportation Systems, with most of the monies being directed to the Space Shuttle programme, and lesser sums going to Space Flight Operations and Expendable Launch Vehicles.

Launching of the Shuttle Orbiter's maximum load into a low Earth orbit is expected in the first half of the 1980s. The Orbiter also will have the added capability of linking up with orbiting spacecraft for inspection, repair or retrieval.

Space Science applications will receive increasing emphasis, with the seven-year total predicted to be $4.6 billion and per annum spending more than doubling in that time. Seven programmes are involved, with Space Telescope Development, Shuttle/Spacelab Payload development, Explorer development and others being the more important in the 1980s.

The remaining NASA Space allocations will be divided among Space and Terrestrial Applications, $2.6 billion, Tracking and Data Systems, $2.2 billion, and Space Research & Technology, $897 million.

DoD's total space appropriations are projected to be $13.8 billion for FY1978-1984, with yearly spending rising 135% in the period, Military Satellite Communications and Air Force Spacecraft Launch and Operations will be the major programme in terms of volume but Space Defence, as noted, will grow to be the second largest programme by FY1984.

The Defense Satellite Communications System (DSCS) will receive the primary thrust among MSC programmes, with the Air Force and the Army contributing funding. The Air Force also will be husbanding its AFSATCOM and Satellite Data Systems (SDS) projects, and the Navy will be developing its Fleet Satellite Communications (FLTSATCOM) plan. The total MSC budget is projected at $4.7 billion.

The Air Force will command over half of Military Satellite Communications outlays with a cumulative budget of $2.6 billion for FY1978-1984. MSC spending by the Navy and the Army, which also has TACSATCOM, is estimated at $1.0 billion each for the period.

To counter Soviet advances in non-nuclear satellite interceptor technology, Space Defense funding will rise from $99 million in FY1978 to $610 million in FY1984. Total appropriations are fixed at $2.1 billion for the seven years. Major emphasis will be placed on Active Space Defense Systems, Space Surveillance and Satellite System Survivability, with other systems also being brought along.

Procurement and RDT&E on Air Force Spacecraft Launch and Operations will increase 122% in annual funding for seven-year budgeting of $3.4 billion. Much of the outlay will be concentrated on the Space Shuttle, with monies also designated for Space Boosters, Space Launch and Satellite Control.

The NAVSTAR Global Positioning System also is forecast for extraordinary gains with annual budgets predicted to expand 321% for a seven-year estimate of $1.5 billion. All military branches will participate but the Air Force will occupy the lead position.

Other DoD Space efforts will be the Defense Support Program at $1.0 billion, Defense Meteorological Satellite Program, pegged at $502 million, and Defense Advanced Space Technology, appropriating $402 million for the period.

The F&S study also notes that, despite budget limitations, NASA will pursue the Jupiter Probe Mission due in January, 1982, and the Space Telescope in late 1983. It also believes the chances are good for the launching of Venus Orbiting Imaging Radar (VOIR) in FY1981, and the Halley's Comet rendezvous mission in FY1982.

*US billion 1,000 million.

"PRIRODA" MOLAB

Soviet advance into the field of Earth resources observation has recently been joined by a special mobile laboratory "Priroda" (Nature) designed to assess the quality of remote sensing by satellites and aircraft.

The programme is being coordinated by the Nature Resources Space Research Institute, the youngest institution within the Academy of Sciences of Azerbaidzhan.

Satellite observations in the USSR now serves agriculture and meteorology, oceanology and geology and methods of comparing the results of space and aerial photography with surface-obtained data allows specialists to forecast the potential agricultural harvest and to prospect for minerals.

Researchers at the Institute say they are working to create "a satellite-orientated flying laboratory." They are particularly interested in using the "Priroda" molab for the study of soil, vegetation, and geological structure.

The mobile laboratory "Priroda" developed in collaboration with scientists of the "Geofizika" research centre. It operates in conjunction with Earth resource satellites to verify their ground truth.

Novosti Press Agency

SPACE AT THE CAPE CANAVERAL AIR FORCE STATION . . . and some other space displays

By Andrew Wilson

Introduction

The US Air Force museum on the Cape Canaveral Air Force Station (CCAFS) contains more items of space interest to the visitor than does its companion museum in Dayton, Ohio, already described by the author in [1]. This article, therefore, takes a look at the exhibits on the Canaveral site. Some minor space display centres – Langley Research Center, SST Museum, Hampton Aerospace Park and Naval Aviation Museum – are also described at the end because *Spaceflight* readers planning tours of the US will find them of particular interest.

Background

The AF Museum at Canaveral should not be confused with the Visitors' Information Center (VIC) which is in the NASA-controlled area of the Cape. The Museum is centred around pads 5/6 and 26, one of the most historic areas of the Cape because it was from here that Shepard and Grissom flew into space during suborbital lobs by the Redstone (pad 5/6) and Explorer 1 put America into the space race (pad 26A).

Numerous launches of the Jupiter missile as part of the NATO training programme for Italian and Turkish crews were made from here, as well as the more newsworthy flights of Ham, Gordo, Able and Baker.

The AF first opened complex 26 as a museum in 1963 and since then it has grown to cover 40 acres and the Services and NASA have donated items obsolete for other purposes. The Museum is run on a shoestring budget and many of the displays have been prepared by volunteers.

The Museum can be visited either by taking one of the NASA bus tours or by hiring a car (there are many hire firms in the area) for a self-conducted tour between 9 a.m. and 3 p.m. on Sundays. The latter course is especially to be recommended because it not only gives the visitor plenty of time to see everything on display but also time to stop off at other points on the drive-through tour. The AF provides a free booklet which helpfully points out landmarks and items of historical interest.

Of course, the Museum has many displays, too many to describe in detail here; for example there is a large collection of missiles (Snark, Minuteman, Jupiter, Polaris, etc). Only the items with direct space connections will be described fully.

Before the visitor actually reaches the gates of the Museum, the gantry and service tower of pad 26 is visible (Fig. 1) with a Juno I launch vehicle in residence. The old, red-painted framework looks antique by today's standards but it gives the tourist an idea of the spirit of those early days of spaceflight. The blockhouse still stands (Fig. 2) and houses the electronic equipment used for those launches (although the firing panel for Explorer 1 is in Huntsville, Alabama).

Fig. 1. Juno I launch vehicle and gantry.

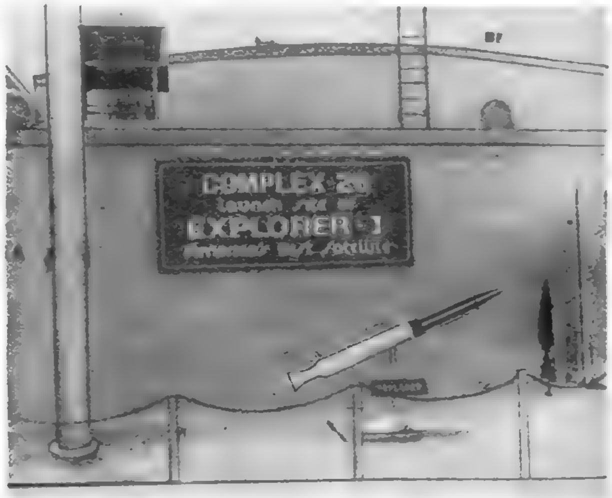


Fig. 2. Launch site of Explorer 1.

Atlas

Many AF bases have an aircraft display which stands as a "gate guardian" at the main entrance and the AF Museum is no exception, although a rocket is used instead of an aircraft. In this case, an Atlas B (number 1410) stands at the gate and gives the visitor a glimpse of the Atlas in its early days (Fig. 3).

The "B" was the first Atlas type to carry out booster and nosecone separation after the "A" had proven the integrity of the unique one-and-a-half stage vehicle. Only 10 "B"s were ever launched, the last in 1959, but the eighth, Atlas 10B, made headline news when it was orbited carrying a taped Christmas message from President Eisenhower under the aegis of Project Score. The "B" on display is not pressurized (as were the flight vehicles) but has had internal strengtheners added. It came from Barksdale AFB, Louisianna, Redistribution and Marketing Branch in 1966.

The Atlas E exhibited in the central display area provides an interesting comparison with the "B" because, together with the "F", the "E"s formed the final operational version of the missile. The major difference between the "E" and "F" was in their methods of deployment: the "E" was stored in a semi-hard coffin and raised vertically for launch whereas the "F" was held in a silo. The "E" was deployed by SAC in 1961 and remained in service until 1965. At peak there were 129 Atlas D, E and Fs held in readiness for launch in sites across the continental United States. All three types were refurbished for use as space launchers.

The "E" (number 58-7126) at the Museum, pressurized and displayed on its transporter, came from Air Training Command, Shepard AFB, Texas in 1965. Fig. 4 shows the missile on its trailer with the Atlas B in the background.

Gemini 2/MOL

On 25 August, 1965 President Johnson gave his official approval to the Manned Orbiting Laboratory (MOL) programme to be used by the AF to orbit sophisticated manned surveillance and

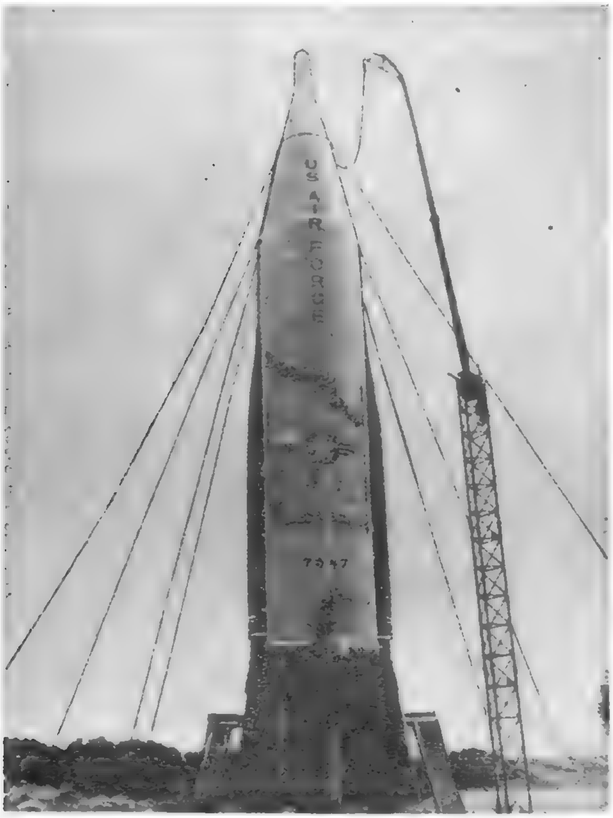


Fig. 3. Atlas B (number 1410) – the "gate guardian".

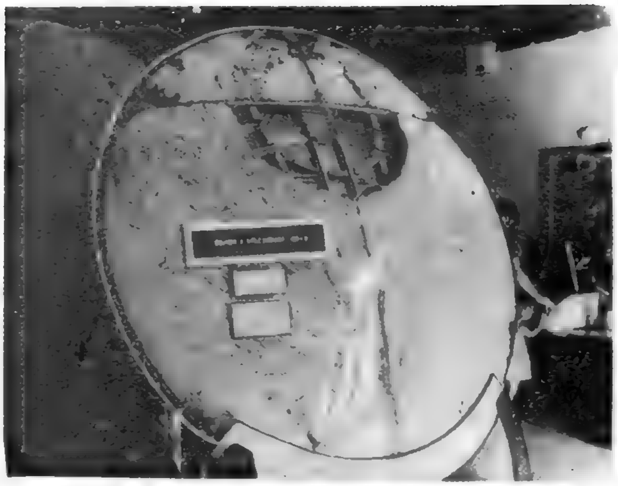


Fig. 5. Gemini 2/MOL capsule showing heatshield and internal construction.

reconnaissance satellites, beginning in the late 1960s. The payloads were to take the form of a "laboratory canister" 41 ft long and 10 ft in diameter, built by Douglas Aircraft and launched by a variant of the Titan III, the IIIM, developed specifically for the project. AF astronauts would occupy the lab for periods of up to 30 days and return to Earth in AF-owned spacecraft.

Since EVAs were full of unknowns in those early days, it was decided to allow the crew to transfer between their Gemini shuttle and the lab by way of a hatch cut into the Gemini heatshield between the two angled astronaut couches. This, however, put the question of heatshield integrity into some considerable doubt and the engineering solution had to be verified in an unmanned flight test which subjected the spacecraft and its modified heatshield to the full heat of reentry. The choice of the test article provides the Museum with a unique exhibit because the AF selected the spacecraft which had already flown as Gemini 2 on 19 January, 1965 when it had been sent on a suborbital heatshield-testing mission before the first Gemini astronauts went into space.

The second launch of Gemini 2, on 3 November, 1966, saw it perched on top of a lengthened Titan IIIC with a Titan II tank below it to simulate the laboratory. The capsule was released on an accelerated ballistic trajectory for reentry while the "laboratory" continued on its way into Earth orbit. The capsule came through its 33 minute flight safely and the Heat Shield Qualification (HSQ) test was judged to have been a success.

In 1965, when DoD approved the start of hardware development, the first of five initial manned flights was scheduled to be flown in 1968 (preventing any clash with the NASA Gemini programme) but 1966 saw the date slip to late 1969.

By 1968 the MOL launch complex at Vandenberg AFB was almost complete and the first static firings of the Titan IIIM first stage had been successfully conducted but the programme as a whole was in considerable trouble because of the budgetary restrictions forced on the country by the continuing Vietnam war. Congress had always regarded the project with some contempt because, they argued, there was a great deal of

Fig. 4. *Below*, Atlas E exhibited in the central display area.

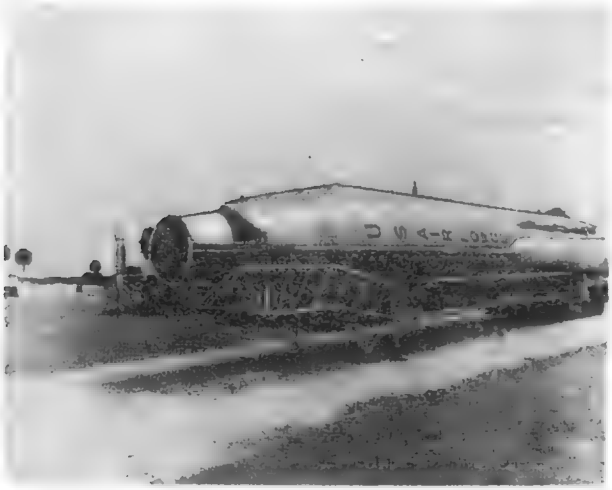
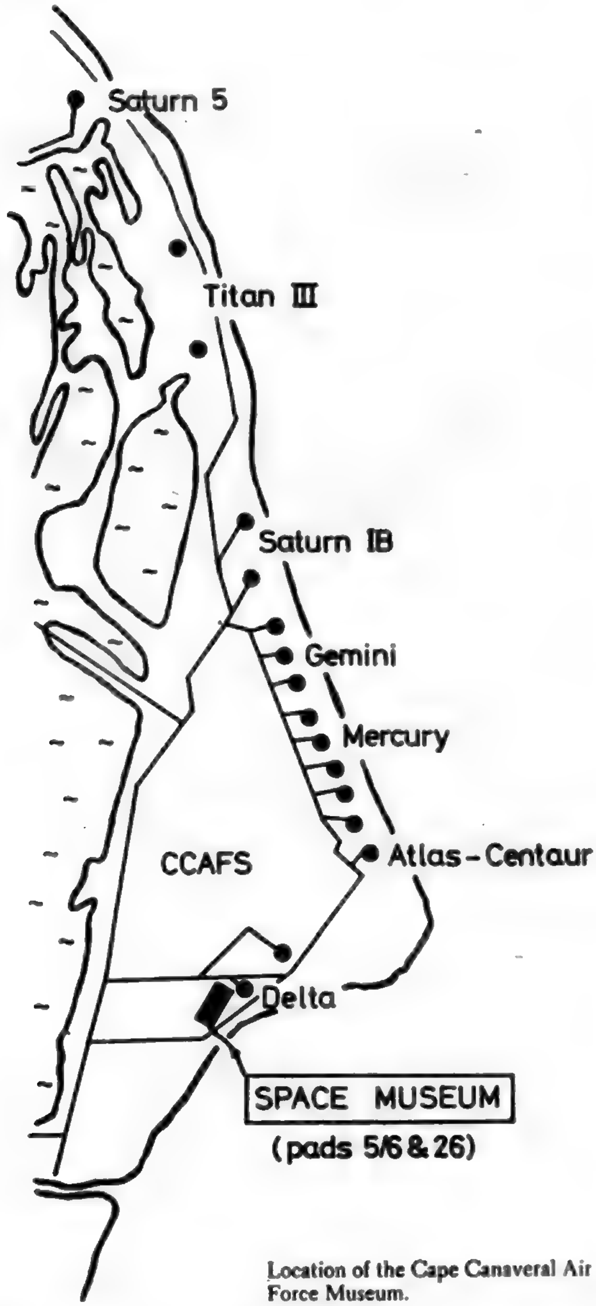


Fig. 6. *Below*, Gemini 2/MOL capsule.



Location of the Cape Canaveral Air Force Museum.

Below, Gemini 3 astronauts Virgil Grissom and John Young (left) during a pre-flight dress rehearsal at Cape Canaveral in March 1965.

duplication between the civilian and military manned space efforts. Systematic cutting of the MOL budget continued until, in June, 1969, it was announced the programme was cancelled. At that time the first manned launch date was 1972 at the earliest. Seven of the seventeen selected MOL astronauts transferred to the NASA ranks in August, 1969.

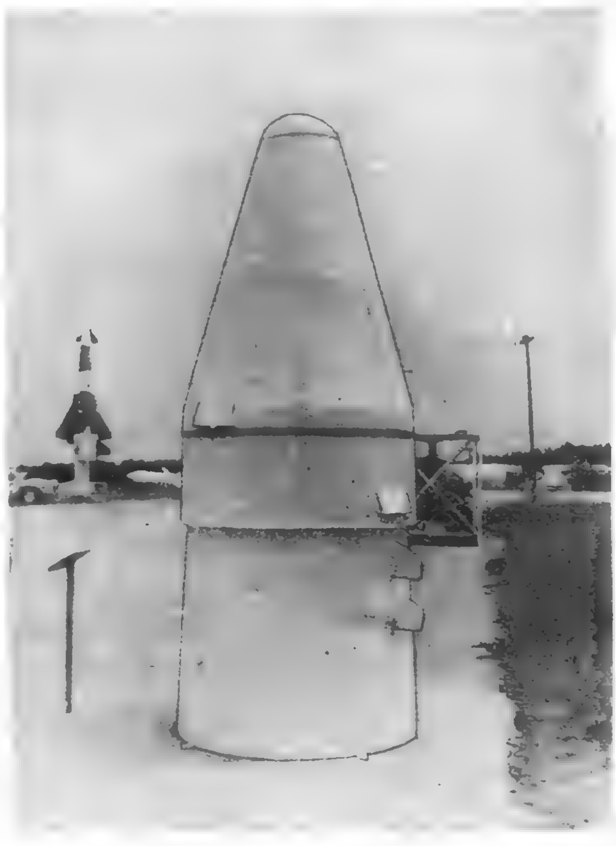
The Museum received the Gemini 2/MOL capsule from the Smithsonian in 1968 and displays it in the building adjacent to the pad 26 blockhouse.

Big Shot shroud

The launch of Echo 1 into orbit in August, 1960 was the culmination of a programme which had already sent six Echo balloons aloft. Echo 1 was the first balloon satellite put into orbit and the inflation techniques and sequence required were the subject of long and detailed investigations in the vacuum chamber with test balloons. The vacuum chamber, however, could not totally simulate the full rigours of a space launch so it was recognised that a series of suborbital lobs should serve to provide the answers before an expensive orbital attempt was made. The series was aptly named "Shotput", in recognition of its spherical payloads and small launchers.

We know Echo 1 was a success in general but it did lose its sphericity rapidly after the inflating gases had leaked out through its thin skin and a wrinkled sphere is not a good reflector for radio waves. Echo 2, therefore, was slightly different in construction and inflation technique, allowing the skin to be stretched beyond its elastic limit to give it a degree of rigidity. Again a suborbital test was deemed necessary and this time the launch was dubbed "Big Shot" in memory of the first series during the time of Echo 1. The test used a modified Thor DM-21 [2] as launcher, carrying the 135 ft-diameter balloon, its container and TV and cine-cameras within the 117 inch diameter shroud built specifically for the project.

Fig. 7, *Below*, Echo 2 payload shroud.



All went well with the test on 15 January, 1962 – shroud separation at T+152s, canister separation at T+165s and balloon deployment beginning at T+195s – until the balloon reached its full size. Perhaps because of rapid expansion of small pockets of air trapped in the folds of the sphere, the skin ruptured. Another test was needed.

For Big Shot 2 on 18 July, 1962, the inflation sequence was slowed down in order to reduce the strain on the fabric and the test subject was seen to inflate satisfactorily via cameras mounted on the Thor. The payload reached an apogee of 922 miles before burning up in the atmosphere on the downward leg of the journey.

Echo 2 was successfully orbited and deployed on 25 January, 1964.

The shroud on display at the Museum arrived through the AF Redistribution and Marketing Branch in 1968 after it had been turned in for salvage by McDonnell Douglas when the programme terminated. It appears to visitors as a very ordinary piece of hardware but, as we have seen, its history makes it an important part of the Museum's exhibits.

Gemini boilerplate

The glamour of manned spaceflight has naturally centred on the men and their machines but neither would have achieved such success without the aid of data from tests on boilerplate spacecraft.

"Boilerplate" is the term for a full-size metal model of a spacecraft, built chiefly for escape and recovery tests. When the Gemini contract with McDonnell was announced in April 1963, the 13 flight-rated vehicles were to be accompanied by other items – simulators, five boilerplates and three static test articles.

The Gemini boilerplates were used extensively in rocket sled ejection, parachute and flotation tests and water egress training but one of their most interesting uses was as test objects in the paraglider drops in the days when it was hoped the Gemini astronauts would be able to guide their vehicles back to dry land with the help of an inflatable Rogallo wing. Development delays meant that this part of the project was dropped but if it had gone ahead we would have seen flight crews being dropped in boilerplates from helicopters as part of their training.

One boilerplate did have a chance of making it into the Gemini flight records when it was selected to become Flight Article 1A to back up the Gemini 1 mission. The Titan II had had a very poor reliability record up to the time of Gemini and planners were none too confident of a successful Gemini 1 flight, so in mid-1963 they scheduled a GT-1A as backup at a cost of about $2 million. The backup was cancelled in February 1964 before the launch of GT-1 the following April when it became evident the Titan II would be able to meet Gemini requirements.

Fig. 8. Gemini boilerplate spacecraft.

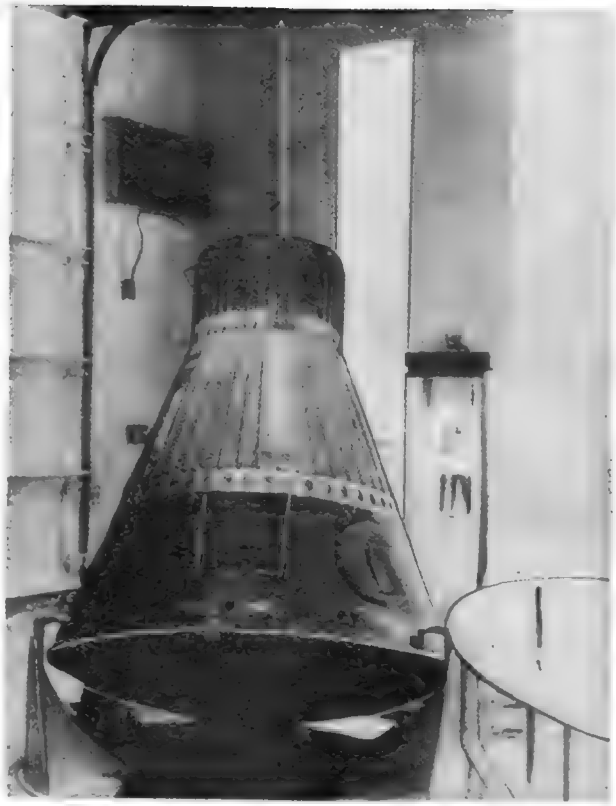


Fig. 9. Gemini backup spacecraft, Flight Article 1A.

Langley Visitors Center

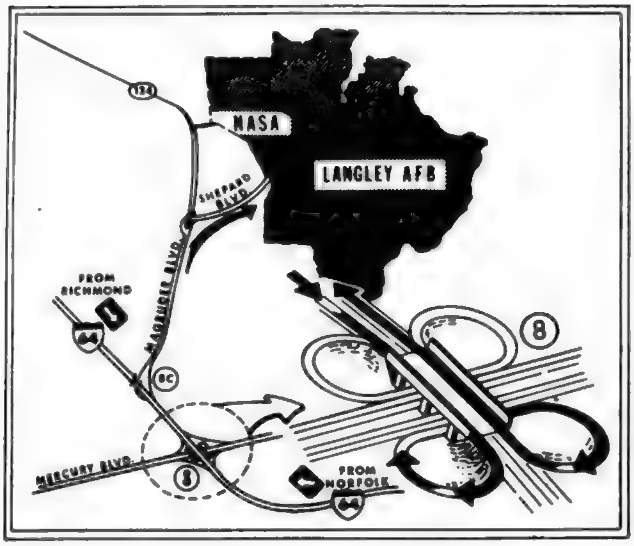
Langley began work in 1917 in aeronautical research and since then it has grown to be a major centre for space work. Its most famous projects were the Mercury and Viking spacecraft and the Scout rocket. It was also responsible for the giant Echo and Pageos space balloons.

The Visitors Center was opened to the public in the summer of 1971 after an extension was built on to an existing office building. The Center, although run by a staff of only ten people, averages some 150,000 visitors per year. A drive-through tour of the area was introduced in the summer of 1976 and takes the visitor past the many wind tunnels and the aircraft crash facility which was once used for training astronauts in lunar landing techniques.

Apollo 12 Command Module

One of the most impressive exhibits at the Center is the Apollo 12 CM "Yankee Clipper". CM-108 was launched at 11.22 EST on 14 November 1969 carrying astronauts Conrad, Gordon and Bean to attempt the second lunar landing, in the Ocean of Storms, a few days later. The launch saw the worst weather conditions known for Apollo and a lightning flash between low clouds and the spacecraft disrupted the main power supply at T+36s and turned on alarms in the CM. Backup battery power was used until the main supply was restored.

Conrad and Bean spent 7½ hours each on the lunar surface in two EVAs, returning parts from the Surveyor 3 soft lander that had been sitting on the surface since 1967.



Location of Langley Visitors' Center.

Fig. 10. Apollo 12 command module.

Fig. 11. Astronauts signatures on Apollo 12 command module.

"Yankee Clipper" safely returned the crew to Earth and their quarantine some 244 hours into the mission, only 4 miles from the *USS Hornet* in the Pacific Ocean.

Fig. 10 shows CM-108 minus its hatch and Fig. 11 shows where all three crewmen signed the spacecraft in the window area. The mission badge above the signatures has four prominent stars on it, three for the crewmen and one for the first LM pilot, C. C. Williams, who was killed in a flying accident.

Big Joe

When the first launches of Project Mercury were still in the future, engineers were undecided on the heatshield design to use on the capsules. The two main candidates were heatsink and ablative but both were still very new and not enough was known about their behaviour under flight conditions. "Big Joe" was therefore evolved to test the spacecraft heatshield under the same conditions which would be experienced by a capsule launched by the Atlas ("Little Joe" did the same for the Redstone). Hopefully, enough data would be collected to allow a clear-cut decision to be made. The launch also provided an opportunity for NASA to gain first-hand experience with the Atlas booster which was then still under development and not very reliable.

The heatshield of the Big Joe boilerplate capsule itself was ablative because there had been problems with producing heatsink shields from beryllium although the spacecraft was designed to allow either type to be fitted.

The main body of the capsule was divided into two parts (clearly visible in the photograph), the lower built by the Lewis Research Center and the upper by the Langley Research Center. Instead of carrying a complete pressure shell the lower half only was pressurised to provide a suitable environment for items such as recording equipment. Over a hundred thermocouples were included to yield temperature measurements in order to allow engineers to recreate the temperature history after the spacecraft was recovered. Eight high-pressure nitrogen attitude jets were carried to rotate the capsule so that its heatshield was directed forward into the line of flight after separation from the spent Atlas 10D.

All appeared to go well with the launch on 9 September, 1959 until observers noted that the Atlas booster engines had failed to separate from the core. This was serious for the flight objectives because the Atlas was now carrying a lot of dead weight and thus being held back from reaching its full speed and correct heading. A more serious problem was that it also led to the capsule remaining attached while the attitude jets futilely tried to turn the whole vehicle. When it did separate the jets were out of fuel and radio blackout at the beginning of reentry prevented engineers from knowing the capsule's orientation. Recovery ships were well off position for a quick pick-up and NASA became worried that the capsule would sink. Fortunately, however, the capsule was picked up and when it was returned to Hangar S at Canaveral engineers discovered the shield to be in excellent condition despite being subjected to much more severe heating than had been planned. A full analysis of the temperature readings verified the initial examination and in fact led to a weight reduction of almost one-half. A second flight, Big Joe 2, was cancelled and the ablative design for heatshields was adapted for the rest of the manned orbital programme.

The Big Joe boilerplate thus became the first of the ten Mercury-Atlas launches and its display next to the Apollo 12 CM reminds visitors how far space technology progressed in the decade from 1959 to 1969.

Apollo 15 spacesuit (David Scott)

For the early manned Apollo missions the astronauts wore the A-7L spacesuit in either intravehicular or extravehicular form but for the more sophisticated J-class Apollos, beginning with Apollo 15, the suit was modified to the A-7LB version. The A-7LB used new types of joints at important body joint loca-

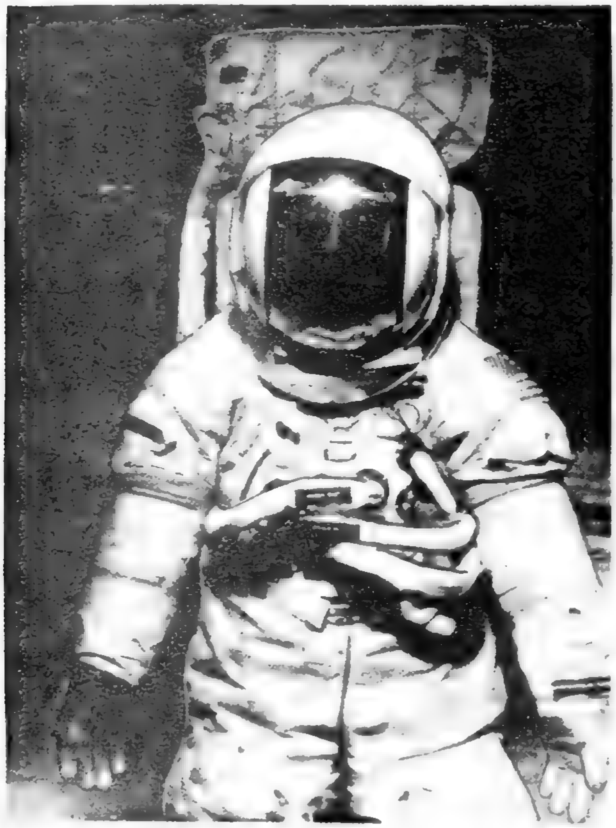


Fig. 12. Spacesuit worn by Apollo 15 astronaut David Scott on the Moon.

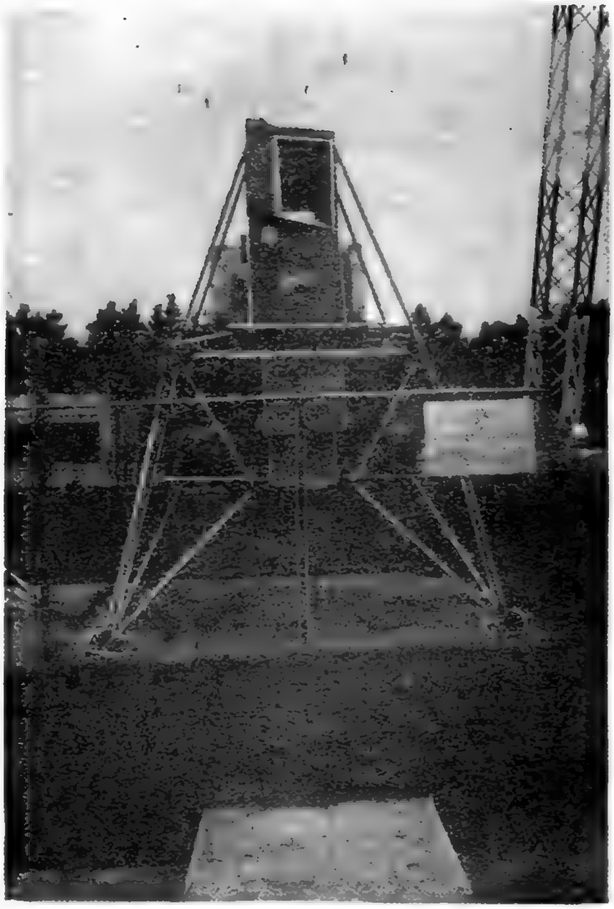


Fig. 14. *Above right*, Lunar Module trainer. The Apollo astronauts used this simulator to practice the final moments of a landing in a Lunar Module. An overhead gantry supported five-sixths of the trainer's weight and a rocket engine below the one-man stand-up cabin provided the thrust to land the simulator.

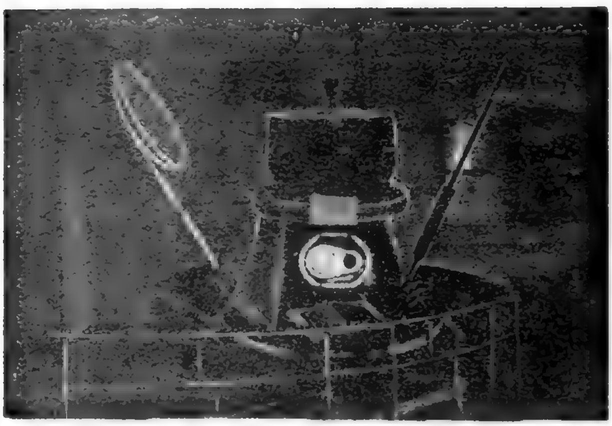


Fig. 13. Lunar Orbiter C, engineering mockup.

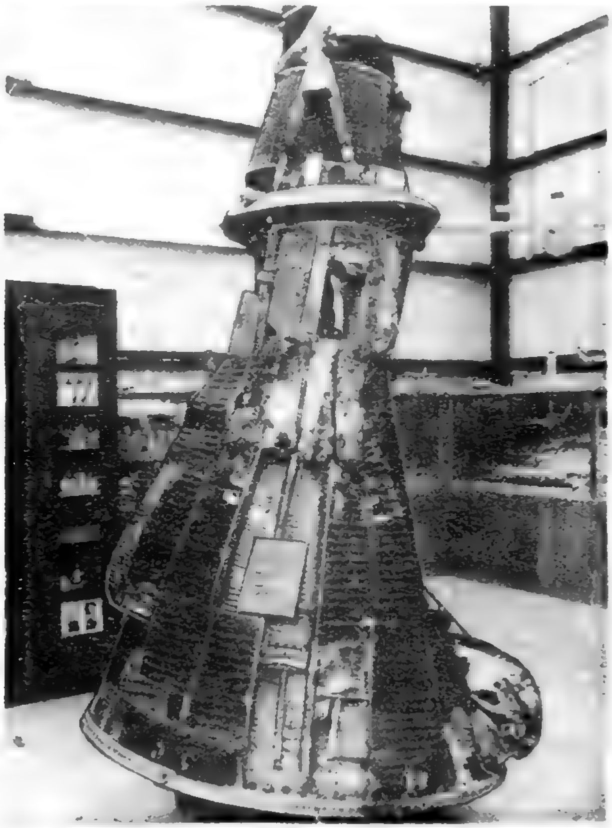


Fig. 15. Mercury capsule 4 re-constructed from debris recovered from the Atlantic Ocean after its Atlas booster exploded.

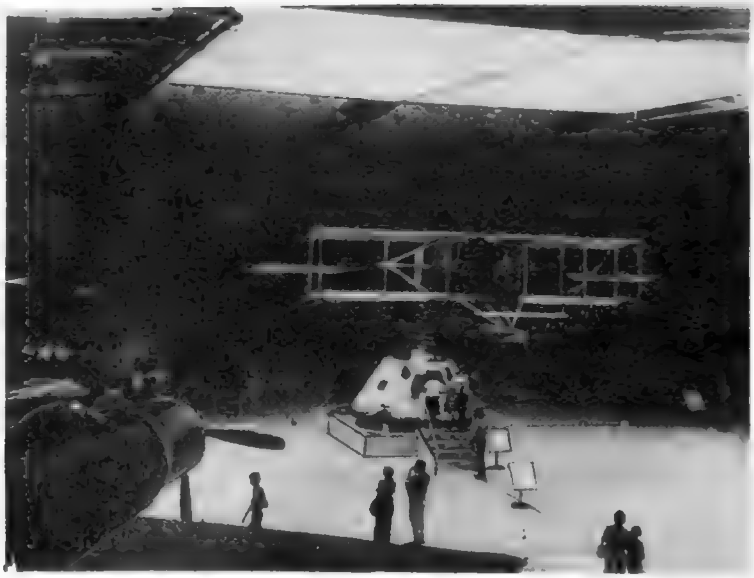


Fig. 16. Skylab 2 command module at the Naval Aviation Museum in Pensacola, Florida.

tions to give greater degrees of flexibility necessary for the longer periods of lunar EVA enjoyed in the later Apollos.

The David Scott suit, on indefinite loan to Langley from the Smithsonian, still bears the mission badge worn during the flight (Fig. 12).

Hampton Aerospace Park

The Langley Research Center is close to the town of Hampton in Virginia which contains several displays of interest to the space observer.

A test Mercury capsule built by LaRC sits atop a Little Joe booster in the outdoor area. The Little Joe programme tested Mercury capsules, some of them off the McDonnell production line, under realistic flight conditions although more severe tests were carried out in the Big Joe launch described earlier.

The Park also has a sub-scale Mercury capsule which was used at Langley in some of the first tests to prove the Mercury design. Another Langley project was the 135 ft diameter Pageos balloon and the Park has the third payload built as a backup to the flight package.

Mercury capsule 4 at the SST Museum

The official histories of Project Mercury do not tell us the fate of the Mercury spacecraft which became the first production capsule to ride into space on an Atlas booster. After Atlas 50D exploded the capsule was destroyed on impact with the Atlantic Ocean and was later recovered for inspection [3, 4]. Its history after that was not well publicized and the author was somewhat surprised to see the reconstructed wreckage of capsule 4 on display at the SST Museum in Kissimmee, Florida, approximately 50 miles from Cape Canaveral. It was presented to the Museum by the two men who located it in shallow water about 7 miles off the Florida coast after its disastrous flight in July, 1960.

The flight of MA-1 should have marked the transition to a near-operational programme by testing a production capsule (capsules 1, 2 and 3 were used in escape tower, Redstone and little Joe tests, respectively) under maximum heating loads from an Atlas launch. The 16 minute flight should have subjected the vehicle to a peak g of 16.3 and the flight appeared to be going well until, with the mission clock barely at T+1 minute, all contact was lost with the Atlas launcher. Telemetry from the spacecraft showed that it survived and remained attached to what was left of the booster – no escape tower was carried – but because of cloud cover at the Cape engineers could not tell whether the accident was owing to an explosion or a structural failure of the rocket. Ground analysis showed the interface between the capsule and its launcher was suspect under certain conditions and this led to future Atlases (although MA-2 was too far in preparation to be fully changed) being built from heavier gauge materials at the forward end.

The failure of MA-1 meant that MA-2 was one of the most important flights of Mercury because had that also failed in such a spectacular fashion the project would have been severely delayed and may have even been cancelled altogether [4].

The photograph shows a view of capsule 4 from its most complete side – at least two-thirds of the external structure is missing.

Skylab 2 CM at Pensacola, Florida

On 25 May, 1973 Apollo CSM-116 carried the first Skylab astronauts, Pete Conrad, Joseph Kerwin and Paul Weitz, into Earth orbit to attempt a daring rescue mission with the crippled Skylab workshop launched 11 days earlier. Their spectacular success is now part of astronautics history and their mission allowed the two subsequent Skylab flights to go ahead.

The CSM of Skylab 2 was ordered from North American before the first lunar landing when it was intended to be used as part of a lunar mission. On the basis that CSM-114 flew with Apollo 17, CSM-116 was therefore scheduled to fly with Apollo 19 but the cancellations of Apollos 18 and 19 in September, 1970 put an early end to its lunar Apollo career. It had, however, been built in the form of a "J" Apollo which meant that it was configured to support a lunar landing of the sophisticated Apollo 17 type but its transference to Skylab service forced engineers to modify it for an extended flight in Earth orbit. The greatest problem was protecting the spacecraft from deterioration on a long-term mission partly because of frequent temperature changes while circling the Earth.

The Naval Aviation Museum in Pensacola, Florida received the CM from the Smithsonian Institution on 18 December, 1973 and exhibits it as the sole space display in the Museum. Appropriately enough, the crew of Skylab 2 were all Naval officers.

The Museum is conveniently located as a stopping-off point for journeys between Houston and Cape Canaveral or Huntsville and Cape Canaveral.

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COSMOS FLIGHTS AT 71°

By Phillip S. Clark

Introduction
On 16 March 1967 – the fifth anniversary of the launch of the first Cosmos satellite – the Soviet Union launched Cosmos 148 into an orbit inclined at 71°, the first time that this inclination was used. In the period to 1977 this inclination was used for a few scientific flights, but the majority of the 72 launches were for unknown military purposes. It is the intention of this review to look at this group of satellites and give a summary of the data which is available.

Launch Vehicle and Launch Site
The non-recoverable* Cosmos flights at 71° used the smallest of the Soviet Union's launch vehicles, the "B-1" (using the classification introduced by Dr. C. S. Sheldon II). This vehicle consists of the SS-4/Sandal launch vehicle, with an orbital stage attached. The writer is presently working on a review of the Sandal programme to be published at a later date, and more details of the launch vehicle will be found there.

The flights came from the northern Plesetsk launch site, which for many years was used for primarily military flights (together with the civilian "Meteor" flights and their precursors).

Sub-Groups of Flights at 71°
There seem to be four sub-groups of flights in the 71° slot when one considers the orbital period. Table 1 provides the number of launches into each of the four groups for the period that the flights took place, while Table 2 lists the satellites which fall into each group. Three of the groups are distinctive (periods 92.2, 93.1 and 95.5 minutes) while the fourth group (period 91.3 minutes) might be somehow connected with the 92.2 minute missions which form the largest sub-group of the flights under consideration. It should be noted that the Sandal launch vehicle seems to have worked fairly accurately since the standard deviation in the perigee heights is ±4 km or less.

Group 1 Flights (Period 91.3 minutes)
There are three satellites in this group and the launches came early in the history of the 71° missions. The perigees are virtually the same as found in Groups 2 and 4 which follow, while the apogee is about 80 km below that found on the Group 2 flights. If these three missions had a wider range in the apogee heights one might consider that the launch vehicle failed to place them in the intended orbit, but this can clearly be ruled out.

It should be noted that the three missions came within three weeks of Group 2 missions, and it is possible that there might be some connection here. The missions concerned are given below, together with the period between the launches.

Cosmos 148 (Gp 1)	Cosmos 152 (Gp 2)	9 days
Cosmos 242 (Gp 1)	Cosmos 245 (Gp 2)	13 days
Cosmos 308 (Gp 1)	Cosmos 311 (Gp 2)	20 days

It should be noted that Cosmos 308 came 17 days *after* the launch of the Group 2 satellite, Cosmos 303.

Using a slightly modified version of the method for calculating orbital plane spacings described elsewhere [1] the orbits of the Group 1 satellites were projected forward in time for a comparison with the (apparently) associated Group 2 flights. There seems to be no connecton between the pairs Cosmos 148/152 or Cosmos 242/245, but within the error bounds discussed in the following section it was found that Cosmos 308 was 60° ahead of Cosmos 311 and 90° behind Cosmos 303. Although the flights were at somewhat different altitudes and therefore the orbits precessed at different rates, the relative orbital plane spacings only changed slightly. The mean precession for the Group 1 flights was −2.701°/day and the corresponding value for Group 2 flights was −2.626°/day, so in ten days the planes separated by only just over half a degree.

In view of the three flights coming early in the development of the main Cosmos 71° programme, it seems possible that they were test-beds for some equipment flown on the subsequent missions in Groups 2 and 4, although this cannot be proved.

Table 1 Summary Totals of Launches by Year

Orbital Period (minutes) Year of Launch	91.3	92.2	93.1	95.5
1967	1	3		
1968	1	3	1	1
1969	1	7		1
1970		7	1	2
1971		8		2
1972		7	1	1
1973		7		1
1974		5		1
1975		3		1
1976		2		2
1977				2
Totals	3	52	3	14

Table 2 Missions Grouped by Orbit and Year of Launch

Orbital Period min	Mean Perigee & Apogee km	Year of Launch	Missions
91.3	271±2	1967	148
	406±1	1968	242
		1969	308
92.2	272±4	1967	152 173 191
	486±14	1968	222 245 257
		1969	265 277 285 295 303 311 314
		1970	321 324 334 351 357 369 388
		1971	393 421 423 435 453 455 458 467
		1972	481 485 487 498 523 524 526
		1973	545 553 558 562 580 608 611
		1974	633 634 668 686 695
		1975	705 725 745
		1976	818 850
93.1	204±2	1968	261
	647±4	1970	348
		1972	*8*
95.5	271±4	1968	204
	814±23	1969	275
		1970	327 362
		1971	391 440
		1972	497
		1973	615
		1974	662
		1975	750
		1976	801 849
		1977	901 919

All missions are identified in the final column by their *Cosmos* serial number. The mission shown in italics is an *Intercosmos*.

The second column shows the mean orbital altitude for perigee and apogee, with the standard deviation indicated (the latter being calculated with "n-weighting").

* *The flights reviewed here should not be confused with the large recoverable Cosmos satellites, launched from Tyuratam into 71.3° orbits.*

Group 2 Flights (Period 92.2 minutes)

This is by far the largest of the four groups considered here, being 52 missions or 72% of the Cosmos 71° programme. The perigee altitudes were virtually constant at around 270 km, but the apogees ranged from 462 km (Cosmos 257) to 514 km (Cosmos 481 and Cosmos 745), where the orbits are taken from the Royal Aircraft Establishment's satellite tables [2]. The apogee altitude varied in a random manner, and does not seem to be connected with the date of launch. The orbits chosen for this group of satellites was such that they repeated their ground track after 31 orbits. At the programme's peak there were about seven flights of these satellites per year, and when the flights ended after Cosmos 850 (1976) no obvious successor appeared for what seems to have been an important programme.

Figure 1 shows a graphical plot of the launch dates of the Group 2 flights vs the satellite lifetimes, and it will be noted that the lifetimes ranged from 61 days (abnormally low, Cosmos 321) to 294 days (Cosmos 705). It is possible to obtain a "best fit" straight line through the points in Figure 1, but a sinusoidal curve seems more natural when considering the end-points. This might be taken to suggest a connection with the varying solar activity (changing the density of the atmosphere's uppermost layers) although the increased apogee altitudes would result in longer lifetimes, as could a change in spacecraft design.

The planes of the satellite orbits were checked to see whether any significant spacings appeared. Here, a "significant spacing" is one which is a factor of 360°, those usually being looked for being 0°, ±30°, ±45°, ±60°, ±90°, ±120° and 180°. The basis of the calculations is indicated in Ref. 1, although as previously noted the method has been modified somewhat. The orbital planes cannot be projected too far into the future because of the low lifetimes of the satellites. For each satellite a check was made to ascertain the satellites which were in orbit at the same time as the one in question and launched after it: the plane of the first satellite's orbit was then projected forward to the times that the subsequent satellites were launched, and the longitudes then compared. The major difficulty with this method is that the rate of orbital precession is not even nearly constant, as will be noted from Table 4. This gives the initial orbits for Cosmos 173 and Cosmos 245, together with an orbit after some months decay has taken place (the orbits are from the RAE Tables). Taking the two precession rate values for the two satellites indicates that over a 30 day period an error of 2.588° and 2.513° would occur in the longitudes of Cosmos 173 and Cosmos 245 respectively.

When the "significant" orbital spacings were looked for, an error in longitude of ±4° was allowed for, although due to the change in precession rate the error bound was widened to ±7°. Table 3 shows the "significant" spacings which were discovered, those with the larger error bound being indicated by an asterisk.

Two of the satellites in this group have been identified as having a scientific purpose. Cosmos 321 and 481 have been stated to have carried out geomagnetic research, but their orbits cannot be distinguished from the remaining Group 2 flights and therefore it seems most probable that the scientific work was only supplemental to the main military programme.

Table 3 List of Significant Orbital Plane Separations

Separation	Missions				
−120°	351/369*	453/458*	481/487*	545/562*	633/686
−90°	311/314	311/324	321/324*	453/455*	611/634
	633/634*	634/668			
−60°	421/423*	481/485*	498/524	498/526*	523/526
	580/634				
−45°	435/467	485/487*	523/524*	523/545*	558/562*
−30°	634/686	455/458			
0°	314/324	467/481	498/523	524/545	608/611
	705/725*	818/850			
30°	435/458	580/611*	580/633*		
45°	285/295*	393/423*	423/435	558/580*	
60°	351/357	388/393	435/455	558/608	558/611*
	668/686				
90°	393/421*				
120°	303/314	487/498			
180°	265/277	357/369	369/388*	423/453*	453/467*
	633/668*	705/745*	725/745		

The above orbital plane separations have allowed for orbits to be separated by ±4° primarily. In cases where the planes are within the wider range ±7° the pair of Cosmos flights is followed by an asterisk.

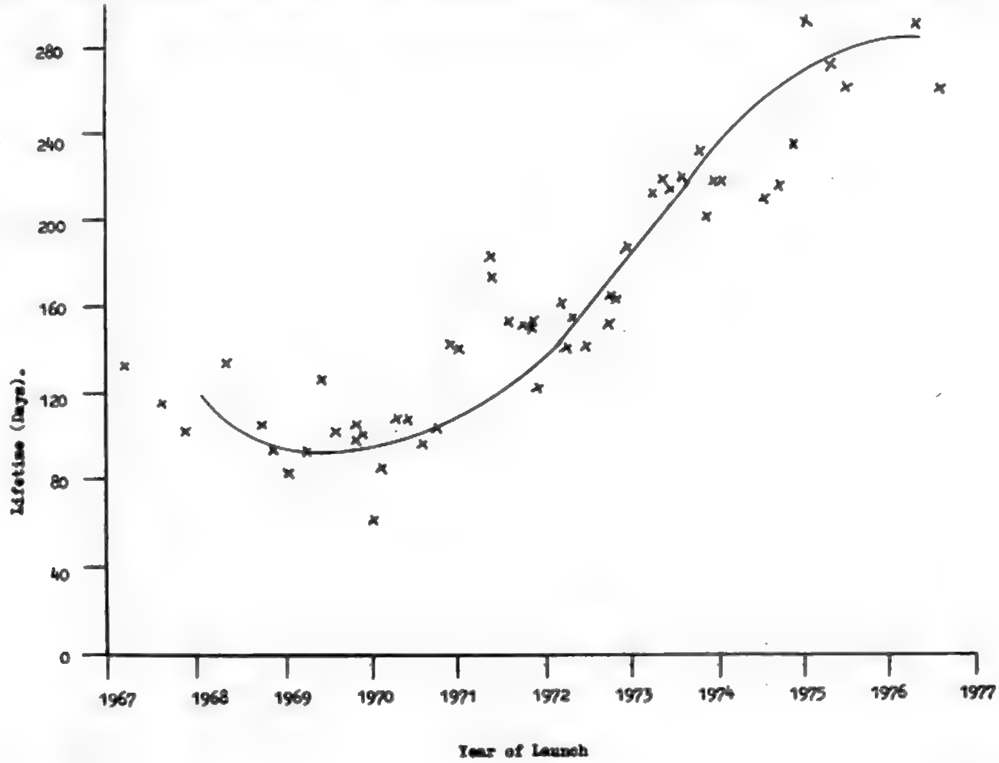

Fig. 1. Plot of Group 2 satellite launch dates vs lifetimes. The sinusoidal curve shows the general trend of the lifetimes during the period considered. If the cycle were to be periodic it would repeat after approximately 13 years.

Table 4 Cosmos 173 and Cosmos 245 – Orbital Decay

Flight	Cosmos 173		Cosmos 245	
Epoch	1967 Aug 24.8	Nov 8.0	1968 Oct 3.7	Nov 30.5
Inclination	71.0°	71.0°	71.0°	70.9°
Perigee, km	277	247	284	253
Apogee, km	480	386	473	403
Semi-major axis, km	6756.5	6694.5	6756.5	6706.0
Eccentricity	0.01502	0.01038	0.01399	0.01118
Orbital Period, min.	92.12	90.85	92.12	91.09
Precession, °/day	−2.64600	−2.73227	−2.64584	−2.72959

The inclination, perigee and apogee values are taken from Volume 1 of Reference 2.

As noted above, the lifetime for Cosmos 321 was far shorter than normal for the Group 2 flights, but that for Cosmos 481 (161 days) was in line with that found for the remainder of the Group.

Group 3 Flights (Period 93.1 minutes)

The third group to be considered consists of three satellites, Cosmos 261, Cosmos 348 and Intercosmos 8 (the first Intercosmos launch from Plesetsk) and these flights have been identified as scientific. In fact, the two *Cosmos* flights would perhaps have been given the *Intercosmos* name if they had not gone from Plesetsk which at that time was not open to foreign scientists. The first two flights were studying the aurorae while the Intercosmos studied the ionosphere.

Calculations show that the orbits for these three missions were chosen to allow the ground track to repeat after 92 orbits (nearly six days). The Cosmos flights had lifetimes of 54 days (Cosmos 261) and 42 days (Cosmos 348), while the Intercosmos had a lifetime of 92 days, the longer lifetime possibly reflecting the change in solar activity when the third flight was made.

Group 4 Flights (Period 95.5 minutes)

The fourth and final group of the Cosmos 71° missions consists of fourteen flights from 1968 to 1977, the last launch (Cosmos 919) being the final orbital use of the Sandal launch vehicle. It will be noted from Table 2 that the range of apogee values found on the flights is greater than that found for any of the other three groups, while the perigee range is about the same as for the Group 1 and Group 2 flights. However, when the standard deviation is expressed as a percentage of the mean apogee it comes to 2.8%, compared with 2.9% for the Group 2 missions. The actual range of apogee is from 780 km (Cosmos 275) to 865 km (Cosmos 849). The orbits of these flights were chosen to allow the ground track virtually to repeat daily, the longitude differing by nearly 1.5° in just less than a day. However, this is for an average orbit, and individual satellites deviated from this slightly.

Table 5 List of Significant Orbital Plane Separations [2]

Separation	Missions
−120°	391/440*
−90°	849/901*
−60°	750/801
−45°	362/391*
−30°	None
0°	None
30°	615/662 801/901
45°	None
60°	750/849
90°	327/391 750/919
120°	801/849*
180°	362/440*

Unless the pair of flights is followed by an asterisk, the separations are correct to ±5°: the pairs which are thus marked are correct to ±10°.

Table 6 Cosmos 204 and Cosmos 440 – Orbital Decay

Flight	Cosmos 204		Cosmos 440	
Epoch	1968 Mar 6.1	1968 Oct 31.2	1971 Sep 30.9	1972 Jun 16.0
Inclination	71.0°	70.9°	71.0°	71.0°
Perigee, km	275	253	272	254
Apogee, km	844	614	785	555
Semi-major axis, km	6937.5	6811.5	6906.5	6782.5
Eccentricity	0.04101	0.02650	0.03714	0.02219
Orbital Period, min	95.84	93.24	95.20	92.65
Precession, °/day	−2.41936	−2.58767	−2.45605	−2.61212

As in the case of Table 4, the inclination, perigee and apogee values are taken from Reference [2].

The lifetimes of the satellites varied with the solar cycle, although the apogee range tends to complicate the matter (see Figure 2). The shortest lifetime was for Cosmos 327 (306 days) and the longest was for Cosmos 750 (805 days).

Due to the longer lifetimes involved with these flights, compared with the Group 2 flights, a greater error bound than previously allowed was used when searching for "significant" orbital spacings. In Table 5 the flights with deviations in orbital plane in the range 5°−10° are marked with an asterisk, while the other flights are within 5° of the separation indicated. Table 6 compares the orbits of Cosmos 204 and Cosmos 440 during their lifetimes and over a 50 day period the orbital planes would vary from those calculated using the initial orbit by about 8° due to orbital decay and the resulting increase in the rate of precession.

Just as the Group 2 flights ended in 1976, the Group 4 flights finished the following year, although here there seems to be the hint of the Skean being used for an up-graded programme. Cosmos 687 and Cosmos 822 were launched in 1974 and 1976 respectively into 280/700 km orbits inclined at 74°. Although no further flights have been made, one is led

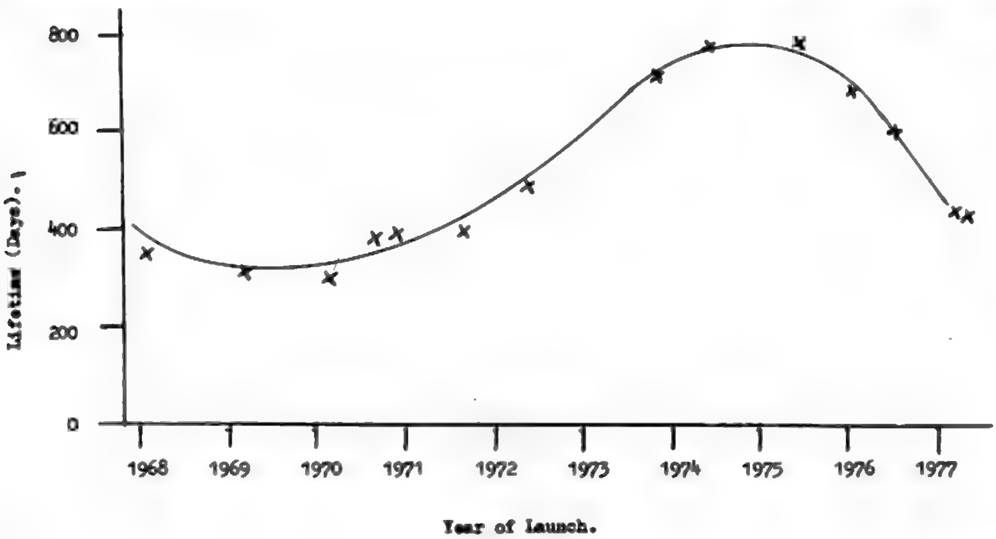

Fig. 2. Plot of Group 4 satellite launch dates vs lifetimes. Due to the variation in apogee heights the curve is not as smooth as in Figure 1. An approximate period derived from this curve is about 11 years. Both Figure 1 and Figure 2 have minima around late 1969, which coincides with solar maximum.

to wonder whether these two flights might have been part of an intended follow-on programme which has yet to materialise.

Purpose of the Flights

It was noted in the Introduction to this review that only a very few of the satellites discussed have had scientific missions announced, and therefore it would seem logical to assume that the main programme for the Cosmos flights at 71° was military. Even two of the flights which have had scientific missions announced (Cosmos 321 and 481 in Group 2) seem to have been *primarily* military in nature.

When looking at the Soviet military space programme one looks for parallels with the American programme, some details of which are available in "open" sources. The Cosmos 71° flights are normally thought to be military ferret flights, and here we have a difficulty in that there is very little information available dealing with the American flights which are assumed to have a similar nature. Sheldon (Ref 3, 402) has listed these Cosmos flights as simply "minor military" without going further than this, and Jasani (Ref [4] 41 & 86-90) suggests a ferret role without being more specific.

One interesting theory for the flights has been put forward by Phil Klass, who is the senior avionics editor of the respected *Aviation Week & Space Technology* magazine. Klass has suggested that the flights, together with similar missions launched from Kapustin Yar into 48°–49° orbits, formed a crude cloud-cover sensing system. Klass sees the flights as supporting the large recoverable reconnaissance satellites in that the smaller satellites could provide weather information over proposed "targets" so that an expensive recoverable flight would not be launched if the target were to be under cloud and therefore unobservable (Ref [5] 157-8). He notes that the Royal Aircraft Establishment's "order of magnitude" dimensions for the Cosmos flights – ellipsoid, 400 kg mass, 1.8 m long, 1.2 m diameter – are roughly akin to those found in the Luna 3 probe which took the first pictures of the hidden side of the Moon in 1959. Luna 3 was an ellipsoid, 1.32 m long, 1.19 m in diameter with a mass of 278 kg. Klass feels that the basic Luna 3 design was up-graded to give a slightly larger craft with more photographic capability to form a cloud-cover satellite for the military.

Klass's theory for these Cosmos flights is the most specific to be found in the "open" press, although by its very nature it cannot be checked.

Follow-on Flights

It is obvious that the series of flights at 71° was important from the launch rate when the programme was in full swing. It is therefore surprising that no obvious successor programme can be found with certainty, since – whatever the missions were – the need for some continuation flights surely exists. It has already been noted that two satellites launched by the Skean vehicle went into somewhat similar orbits, although the two flights came while the Sandal payloads were still being launched. Apart from the two Skean flights, no missions have been flown in orbits similar to the 71° missions.

In the 1970s the recoverable reconnaissance satellites launched by the Soviet Union have become more versatile with satellites having lifetimes of around two weeks taking the place of the original "8-day wonders". In September 1975 Cosmos 758 was launched into a typical reconnaissance satellite orbit but at an inclination of 67.1°. Although the initial flight was possibly unsuccessful, subsequent flights have remained in orbit for up to a month and presumably this fourth generation reconnaissance satellite will at some stage take the place of the current third generation missions. The fourth generation craft probably have masses of up to 7,000 kg. Since the initial flight of the fourth generation recoverable flights came when the 71° programme was being phased out, it is possible that ferret equipment is being carried on the newer craft, in which case the fourth generation reconnaissance satellite would be performing both high level ground photography and the more general ferreting work. Certainly the increased lifetime of the fourth generation craft is more useful for ferret work than the short-duration third generation vehicles.

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SKYLARK RECORD

A Skylark 12 rocket produced by British Aerospace has been launched to a record height of 518 miles (834 km) from the launch site at Barreiro do Inferno, Natal, Brazil. The space shot was part of the West German sounding rocket programme planned and organised by the German Space Agency (DFVLR) in a programme of scientific cooperation with Centro Technico Aerospatial (CTA), Brazil.

All systems of the three-stage Skylark performed correctly and the scientific mission to investigate helium gas concentration in space by scanning at certain wavelengths above 188 miles (302 km) was a success.

Skylark rockets are prepared and launched by DFVLR in the Federal German programme of geophysical and astrophysical research and materials science in microgravity conditions.

This was the 379th Skylark to be launched to date, and the 20th in the programmes conducted by DFVLR.

POSTAL INCREASES AND THE SOCIETY

The large increases in UK Postal rates combined with increased printing costs for our publications, are placing a heavy burden on the Society. As a necessary economy measure we are therefore asking all members corresponding with the Society, and requiring a reply, to kindly enclose a stamped-addressed envelope or international reply coupon. Ed.

'The Mystery of Luna 10 and Luna 11' by Phillip S. Clark. We much regret that the author's name was omitted from the above article which appeared in the December 1979 issue of *Spaceflight*, pp 520–21.

CALL FOR PAPERS One-day Symposium
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OUR DESTINY IN SPACE

By Gerald L. Borrowman

INTRODUCTION

Three days after the 10th anniversary of man's first expedition to the lunar surface the Space Shuttle Enterprise ended its career as she was rolled back to the Vehicle Assembly Building from Pad 39A at the Kennedy Space Center. Only a few hundred feet away, as Apollo 11 departed the pad, Vice-President Spiro T. Agnew had appeared on television along with CBS anchorman Walter Cronkite and called for a manned expedition to Mars.

Vice-President Agnew chaired the Space Task Group which released its report in September of 1969. It stated:

The next national step for us (the United States) in space will be for us to create permanent manned space stations in Earth and lunar orbits with low-cost access by reusable chemical and nuclear rocket transportation systems, and to utilize these systems in assembling our capability to explore Mars with men, thereby initiating man's permanent occupancy of outer space. The key to carrying out this step in an effective and efficient manner will be commonality – the use of a few major systems for a wide variety of missions; reusability – the use of the missions; and economy – the reduction in the number of "throw-away" elements in any mission, the reduction in the number of new developments required, the development of new programme principles that capitalise on such capabilities as man-tending of space facilities and the commitment to simplification of space hardware[1].

NASA believed that its expansionary projections were realistic and that they had an ally in President Nixon, who had always shown a keen interest in the space programme. From October 1969 through the spring of 1970, Thomas O. Paine, then NASA's administrator, had talks with government and industrial officials of these countries, briefing them on NASA's goals for the future.

The Collapse of "Post-Apollo"

Keen competition for federal dollars did not allow for a space programme approaching the scope of NASA's ambitions. Even President Nixon's closest political and budgetary advisors felt that with the accomplishment of the manned lunar landing space was no longer as important as it had been. NASA's greatest difficulties were to be in its dealings with the President's budget office, the Office of Management and Budget. Accustomed to the *carte blanche* treatment it received during the peak development years of Apollo, NASA's fiscal 1971 budget was flatly rejected. This included a reduction from $170 million to $80 million for the Shuttle. In response NASA dropped Apollos 18-20.

This indicated that post-Apollo lunar missions and manned expeditions to Mars were too expensive to be undertaken in the near future. The lofty dreams of the Space Task Group were a shambles. Ten years later the space programme had become but another pawn in a series of White House political manipulations and a victim of fiscal strangulation at the hands of the Office of Management and Budget.

With the launch of the Shuttle delayed by more than a year it is now clear that the level of funding is a source of many of the delays and frustrations[2]. While the day-to-day conduct of America's space programme suffers from such interference Apollo astronaut and now Senator from New Mexico Harrison Schmitt has introduced two space policy bills that in effect express the view, "Yes, we can move forward; and in that arena it is one of the most fundamental arenas where we can move forward . . ."

Before the Committee on Commerce, Science, and Transportation of the US Senate James Michener who described himself as a student of "the rise and fall of nations" and in so doing had reached certain conclusions governing that process. "There seem to be great tides which operate in the history of civilization," he said, "and nations are prudent if they estimate the force of those tides, their genesis and the extent to which they can be utilized."[3].

Senator Schmitt responded, ". . . that the torch has been passed (to) a new generation of individuals in the Congress who are aspiring to leadership, if not in leadership."

Senator Schmitt queried Michener as to his estimation of the impact of the birth of the first person on Mars as compared to that of the first individuals to settle in the New World.

Michener's response was:

"It seems to me the analogy is almost exact. The thought in Portugal in 1450 when they first visualized they could get around Africa and hit the great riches of the East. It must have been an awakening of the magnitude that only we have had with landing on the Moon and the exploration of Mars."[4].

Michener in his statement had outlined the situation in mid-15th century when nations were faced with the option of participating in the exploration of the world in light of the discoveries of individuals like Columbus, Vasco da Gama and Sebastian Cabot. Prompt decisions were made by Portugal and Spain which gained them empires of fantastic riches. Germany and Italy failed to perceive the possibilities and suffered grave disadvantages and never caught up. While England and France were tardy in exercising their option, the former succeeded in making a stunning recovery while the latter failed.

To have been excluded from the spiritual awakening was disastrous. Michener saw no harm "if a nation responds to a challenge, succeeds in its efforts, garners the rewards for a sensible period. . . . I think no harm has been done. The nation has gleaned from that experience about all that it was destined to achieve, and a great good has been accomplished, because then the nation is prepared psychologically to tackle the next big problem when it comes along. And it surely will, for the life of any nation since the beginning of history has been a record of how it confronted the great challenges that inevitably came its way"[5].

That is just what John Kennedy had intended for Apollo ". . . to him, the programme was only secondarily about scientific or military benefits. It was about politics, in a grand sense: it was about defining and shaping the nation's spirit and confounding its enemies."[6]

AIMS AND OBJECTIVES

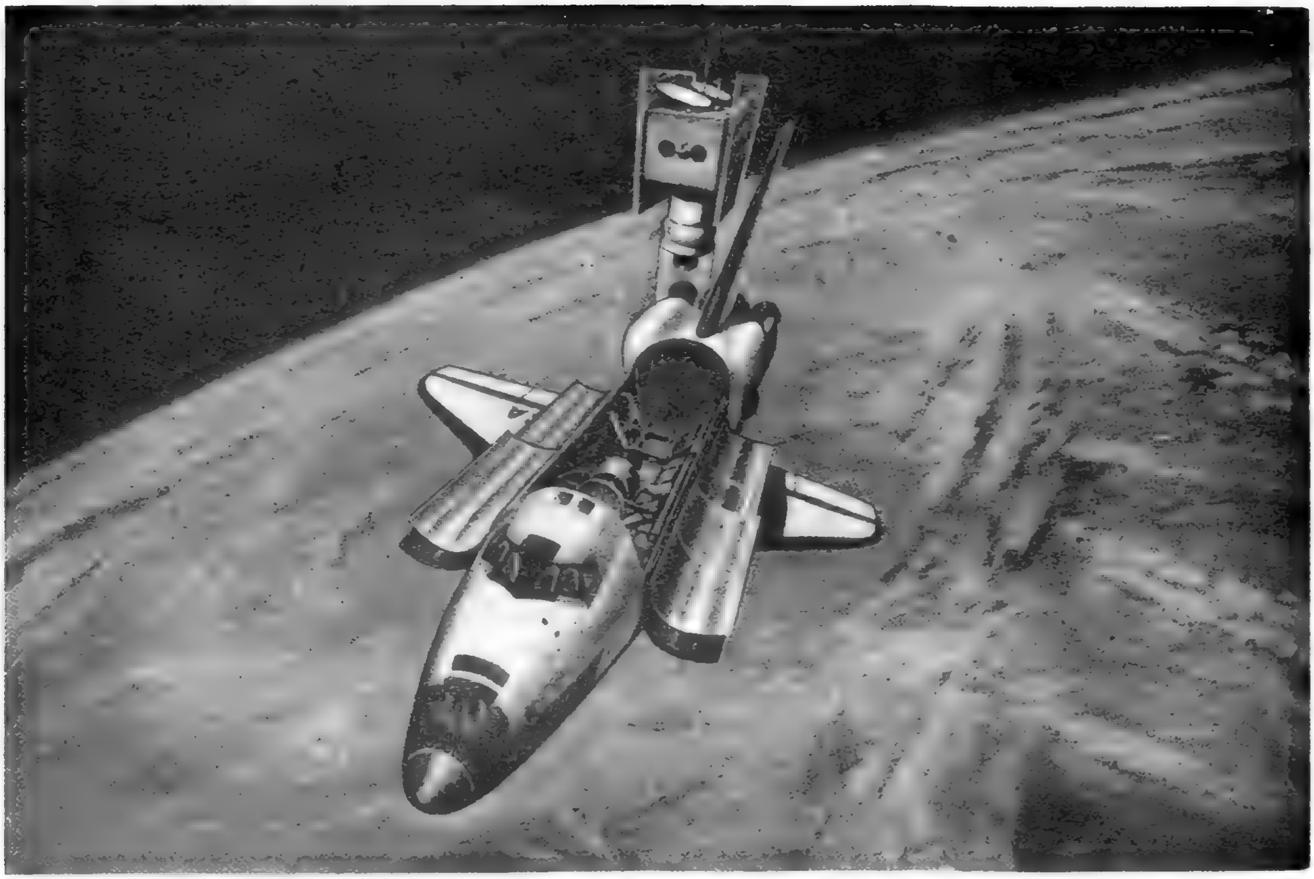
What is to be the goal and scope of America's space programme? NASA's administrator expressed the view that the space programme no longer required "a particular internal objective (as the lunar landing) in order to do the technological work."

Schmitt responded, "You may not be funded unless you have some interesting things to do. You may have a chance internally (within NASA), but you just may have a problem up here on the Hill."

He then went on to outline his own criterion for a successful space programme. "I think the . . . policy, in most respects, is only going to be successful if, in fact, it's exciting, particularly within the United States, in America – let's say, American history. We're very much focused on doing exciting things. It's inherent in our whole history. It doesn't mean that they're not worthwhile things, but we certainly do like to do exciting things, and I think we do them very well.

"Whenever we realize there's a crisis, and we have the time to get ready to do something about it – so far, we've handled those crises extraordinarily well.

"The same goes for doing very spectacular things, like the



HOPE FOR THE FUTURE - the "maid-of-all-work" Space Shuttle pioneered by NASA. In this artist's impression a communications satellite is being released from the cargo bay. The satellite's multichannel communications system is compatible with both conventional ground receivers and small, low-cost antennae. A small rocket will boost the satellite to Clarke orbit 22,300 miles (35 800 km) above the equator.

Rockwell International (painting by M. Alvarez)

Apollo programme - spectacular programmes, not one-shot spectaculars."

Schmitt called on Frosch to use his influence with the Carter Administration in the creation of balanced budget programmes and framework policies. A prerequisite for success in the view of Schmitt was exciting directions for America's space programme.[7].

Since the level of activity in space is largely an action-reaction cycle with the Soviets, the US programme may be about to receive a much needed boost. In early August Roald Zummuritch Sagdeyev in a broadcast from Moscow revealed that the Soviets are currently studying how long cosmonauts can live and work in space in preparation for a manned mission to Mars. This is the first time that a top Soviet official has been quoted on a direct reference to Soviet plans for manned missions to the planets.

US Rep. Bill Nelson who represents the area including the Kennedy Space Center, described the possibility of a formal Soviet announcement to send a manned mission to Mars as one that "could very well help the US space effort. ... If we find out officially that they are going to Mars it could very well help the US space effort ... It would refocus the nation's attention on man's achievements in space ... (and) inject some competitiveness which would make our job in the Congress of funding the space programme easier.

"We are at a time where we are trying to get the Space Shuttle up and this (Soviet statement) could help us get the needed money for the project."

"The acquisition of funds for the US space programme could be considerably eased if the Russians formally announced they are going after a space spectacular, like a manned Mars mission."

THE INSPIRATION?

What does it take for Americans to do great things, to go to the Moon, to win wars, to dig canals between oceans, to build a railroad across a continent? In the wake of a unique Caltech conference of Apollo astronauts, managers and scientists in August of 1975, Neil Armstrong and Harrison Schmitt independently concluded that four conditions involving the simultaneous peaking of four of the many cycles of American life.

First, a base of technology must exist from which the thing to be done can be done.

Second, a period of national uneasiness about America's place in the scheme of human activities must exist.

Third, some catalytic event must occur that focuses the national attention on the direction to proceed.

Finally, an articulate and wise leader must sense these first three conditions and put forth with words and action the great things to be accomplished.

The motivation of young Americans to do what needs to be done flows from such a coincidence of conditions.

In regards to the present situation on the frontier of space an articulate and wise leader is lacking[8]

The challenge for a space policy that will sustain the movement of the civilization of freedom into space is to create the technology base by which future leadership can move in directions dictated by events. The Tom Jeffersons, the Teddy Roosevelts, and the John Kennedys will appear. We must begin to create the tools of leadership which they and their young frontiersmen will require to lead us onward and outward.

An avenue for a greater number of people to become involved with the Space Shuttle was recently opened when NASA announced that it will begin accepting applications on an annual basis for astronaut candidates. NASA accepted applications between 1 October and 1 December 1979 for pilots and mission specialists. The latter were required to have a bachelor's degree in engineering, biology, physical sience or mathematics and at least three years experience in their field.

Space constitutes one of the compelling challenges of nature that if missed is tantamount to missing the *raison d'etre* of an epoch. Nearly four hundred years ago William Shakespeare wrote:

There is a tide in the affairs of men,
Which, taken at the flood, leads on to fortune;
Omitted, all the voyage of their life
Is bound in shallows and in miseries.
On such a full sea are we now afloat;
And we must take the current when its serves,
Or loose our ventures.

Bob Crippen the pilot for the first flight of Columbia put it in his own words, "... the capability to get in and out of space easily will allow us ... to really use space. It's been in its infancy so far and the results are going to be felt not by my generation ... I think that future generations will thank us for having pursued it and we at NASA spend a great deal of time preparing ourselves for coping with problems."

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NAMES OF US MANNED SPACECRAFT – PART 2

By Curtis Peebles

[Continued from 'Spaceflight', February 1978, p. 70.

Naming the Shuttles

By late 1978, the glide flights of the Enterprise were history. The first shuttle was undergoing the less spectacular, but still important, series of vibration tests at Huntsville. Shuttle 102, the first to fly into space, was nearing completion. In preparation for its transfer from Palmdale to the Cape, NASA Headquarters began searching for both US and International ship names that played a major role in man's first epoch of exploration on Earth.

On 25 January, 1979, NASA Administrator, Dr. Robert Frosch, announced to a Congressional sub-committee the names that had been selected, Shuttle 102 was named Columbia after the sloop which entered and explored the Columbia River in 1792. Captain Robert Gray named the river for the ship. This was, also, the name of one of the first US Navy ships to circumnavigate the world and, also, the name of the Apollo 11 Command Module.

Shuttle 099, the former structural test article, is to be named Challenger after the HMS Challenger which conducted the first systematic exploration of the world's oceans from December 1872 to May 1876. This voyage formed the basis of oceanography. Its findings filled some 50 volumes. It is, also, the name of the Apollo 17 Lunar Module. It was the last US manned spacecraft to land on the moon – 100 years to the month after the original Challenger set sail.

Shuttle 103 is Discovery for the ship which explored Hudson Bay and searched for the Northwest Passage between the Atlantic and Pacific in 1610 and 1611. It was, also, the name of one of the two vessels which made Captain Cook's third and last voyage – 1776 to 1780. The voyage covered the central and northern Pacific and included the discovery of the Hawaiian Islands[1]. It was the name of Commander Robert Scott's steam bark which made the first scientific survey of Antarctica[2].

The last of the planned shuttles, 104, when completed in the mid-1980'S, will be Atlantis; this in honour of a wooden ketch built in 1931 and operated by the Woods Hole Oceangraphic Institute. For over 30 years, it was the only ship in the US research fleet designed specifically for research[3]. Dr. Frosch, before coming to NASA, was associate director for applied oceangraphic research at Woods Hole[4].

The complete list of the space shuttles is:

101 Enterprise
102 Columbia
099 Challenger
103 Discovery
104 Atlantis

The X-15

The orbital space flights of the early 1960's over-shadowed NASA's aeronautical research. Yet this research provided much of the data base for the shuttle. One of these research aircraft was the X-15 an aircraft so powerful it could reach an altitude of over 50 miles (80.65 km), qualifying its pilot as an astronaut. Officially, the three X-15s built were known as 1, 2 and 3. However, for one flight the third X-15 did carry a name. During the preparation for Joe Walker's record August 1963 flight, the name "Little Joe the II" was painted on the aircraft's nose[5].

The original Little Joe was the informal name of the X-1E, the last of the original X-1 series. Walker was deeply involved in the construction of this aircraft during the mid-1950s[6].

On 22 August 1963, Walker and Little Joe the II reached an altitude of 354,200 ft (107,988 metres). This was the highest flight made by a manned aircraft, a record which has lasted until the coming of the shuttle[7].

Had Events Been Otherwise

Shakespeare said "a rose by any other name" but what of spacecraft? Here are a few of the also-ran names, ones that never quite made it to the launch pad. John Glenn studied such names as Liberty and Independence. Carpenter almost named MA-7 Rampart after the Rampart Mountain range in Colorado. For MA-8, Schirra considered Phoenix or Pioneer[8]. Had the three-day MA-10 mission been flown, the capsule would have been named Freedom 7II by Alan Shepard. On 11 May 1963, however, NASA announced that it would not be flown[9].

John Glenn climbs into his "Friendship 7" Mercury capsule at Cape Canaveral on 20 February 1962. Earlier suggested names were "Liberty" and "Independence". NASA

Most are aware of Grissom's selection of Molly Brown for Gemini 3 and the controversy that resulted. But less widely known is that Grissom originally selected Wapasha. This is the name of an Indian tribe after whom the Wabash River was named. The name satisfied Grissom's desire for a truly American name. Unfortunately, somebody reminded Grissom that, inevitably, the mission would be dubbed "the Wabash Cannon Ball" after a famous American train. Grissom's father, however, worked for the Baltimore & Ohio railroad which clearly made Wapasha unacceptable for family reasons[10]. He finally selected Molly Brown from the play "The Unsinkable Molly Brown" in memory of the loss of Liberty Bell 7. His selection met with the less than unanimous approval of NASA management and he was pressed for a second choice. Mrs. James J. "Molly" Brown, the flamboyant Denver millionairess, received the nickname "unsinkable" due to her surviving the events of a cold legendary April night over 50 years before[11]. It was therefore logical that Grissom's second choice was Titanic[12]. It is tempting to say that if Grissom had stayed with Wapasha, there would have been no battle and no order forbidding names; yet it should be noted that opposition to naming spacecraft had occurred as early as Cooper's flight in MA-9. Some in NASA questioned the selection of Faith 7, quoting the inevitable headlines in the event of disaster "America loses Faith"[13].

The most care was given to the choice of names for Apollo 11; literally hundreds of names were suggested. Among the losers were: Romeo and Juliet, Antony and Cleopatra, Daphnis and Chloe, Castor and Pollux, David and Goliath, Owl and Pussycat and Majesty and Moon Dancer. Inserting any of these in the following sentence "Tranquility Base here, the —— has landed" indicates the wisdom of the final selection of Columbia and Eagle[14].

In February and March of 1970, several sources stated that the Apollo 13 Command Module was named Auriga[15]. The constellation Auriga represents a charioteer[16]. Since in Greek mythology the God Apollo drove the chariot which carried the Sun across the sky each day, it was an appropriate name. But as history records, the Command Module flew as Odyssey. It would seem, on the surface, that Auriga was the original name and was replaced at the last minute by Odyssey. Captain James Lovell recently clarified the matter: "Although the name Auriga has been mentioned, it was never seriously considered for the Command Module"[17]. The crew studied names from mythology; Odyssey was chosen because of the dictionary definition of the word "a long voyage with many changes of fortune".

"The Lunar Module was named Aquarius", said Lovell "after the Egyptian goddess, the water bearer, who brought fertility and knowledge to the Nile River. We thought the name was appropriate because the Lunar Module would bring knowledge from the Moon."

There was, in fact, no late change in names. The only question is how the reports originated. One possibility can be found in the Apollo 13 patch. It shows Apollo's chariot carrying the Sun. The patch was first unveiled on 23 January 1970, considerably before the 14 March press conference by Lovell, Haise and Mattingly where they announced the names[18]. Whatever the explanation, it was a matter of error, rumour and conjecture.

Conclusions

It is fitting that the names of ships of exploration were selected for the shuttle. For the shuttle, like those earlier voyages, will extend man's knowledge of the Earth and its place in the universe. The technology of sailing ships and space shuttles are separated by more than years, yet, the same spirit of exploration links their voyages.

Acknowledgements

I would like to express my thanks to James A. Lovell for his information about Auriga: also, to the individuals who wrote to *Spaceflight* concerning the original article; in particular Andrew Wilson, John Catchpole and Philip Snowdon.

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THE DISPOSAL OF NUCLEAR WASTE: THE SPACE OPTION

By David H. Hinson

Introduction
There are basically four ways of dealing with waste material. We can destroy it, recycle it, dilute and scatter it about so that no one place has an unacceptable level of waste, or isolate it from the environment until it has decomposed into harmless substances. None of these methods can be easily applied to the problem of high-level nuclear waste. Its destruction, by transmuting long-lived radionuclides into short-lived or stable isotopes, seems infeasible with present technology. Recycling is not a complete answer; since there are so many different radionuclides in the waste, a use for each and every one is unlikely to be found. Also, the proposed recycling of plutonium for use in commercial power plants has aroused controversy in recent years. Unlike reactor-grade uranium, plutonium could be readily used to build nuclear weapons. Many fear that nuclear proliferation would increase, and even that plutonium could be hijacked by terrorists who could make their own bomb or use the plutonium to pollute the environment. In view of all this, most of the discussion on high-level nuclear waste has been on the isolation of the waste from the biosphere.

Methods of Isolation
There are two basic ways to isolate something from the environment. First, the waste can be stored in some impervious, sufficiently durable container. Both natural and artificial containment media have been considered; including granite, bedded salt and the Antarctic ice cap. However, while most of the initial radioactivity is due to fairly shortlived isotopes that decay to safe levels in a few centuries, longer-lived isotopes that require hundreds of thousands of years to do so are present in significant quantities (Moghissi, 1978). The high initial heat output of the waste is a great problem, as is the fact that maintenance cannot be assumed for thousands of years. No proposed method of disposal has won the approval of the scientific community.

The other method of isolation is to put a great distance between the material to be isolated and the place from which it is to be isolated. In the case of high-level nuclear wastes, this means removal from the Earth itself, i.e. ejection into outer space.

If this method is to be used, care should be taken in deciding where it should be sent. Random ejection into space would likely lead to some of the containers crashing to Earth before their radioactive cargo could decay to a safe level.

Several factors should be considered in deciding between alternative extra-terrestrial disposal options:

(1) How safe is it? If the mission is successful, will the waste stay where we have placed it?
(2) In the event of mission failure, how likely is an undesired re-entry? Also, how difficult would the recovery of a waste container in an undesirable orbit be?
(3) How much would the disposal scheme cost?
(4) Would it interfere with other space missions and scientific research?

The Space Option
In this article, it is assumed that the waste is launched from low-Earth orbit, 115 miles up, having been placed there by a Space Shuttle or some similar device. The use of a recoverable vehicle for the first part of the trip results in considerable savings over the use of an expendable vehicle for the entire mission, from ground to final destination. The safety and economic aspects of launching high-level wastes into orbit on the Shuttle will not be considered here. However, it does seem likely that only the long-lived portion of the waste would be disposed of in space, to cut down on the number of launches needed (Alternative Technology Strategies, 1978).

THE SEARCH FOR A NUCLEAR "DUSTBIN". Is the disposal of nuclear waste in space a realistic or even a desirable option? This article reviews the prospects as the world converts from fossil fuels to a nuclear energy future.

Rockwell International

The overriding economic factor in a particular space disposal concept is the amount of energy required to move it from low-earth orbit to its desired location, and to give it the proper velocity if it is to be stored in a particular orbit. For example, putting a waste container into a circular orbit around the Sun is a three step process.

First, we must give the vehicle enough velocity so that it escapes from the Earth's gravity. From a 115-mile orbit, this is 2.86 miles per second.

Second, the canister must be placed in a transfer orbit. The lowest-energy (and therefore cheapest) transfer orbit is an ellipse with the Earth at one extreme end and the destination at the other. If the destination is closer to the Sun than the Earth, then the destination is at the closest approach of the transfer orbit to the Sun, while the Earth is at the point in the transfer orbit farthest from the Sun. The reverse is true for disposal outside the Earth's orbit.

Third, once the destination is reached, the engine must be fired to remove the vehicle from the transfer orbit and place it in the proper circular orbit. If this is not done, the waste would eventually return to near-Earth space (barring perturbation). It could eventually crash to Earth.

The total required velocity change (or delta-V) is the sum of the velocity changes required for each part of the mission. The delta-V required for a mission determines how much fuel must be expended for a given payload mass. While there are other economic considerations (for example, longer missions would require more reliable and expensive instrumentation and storable propellants), it is reasonable to consider the cost of a mission as proportional to the required delta-V.

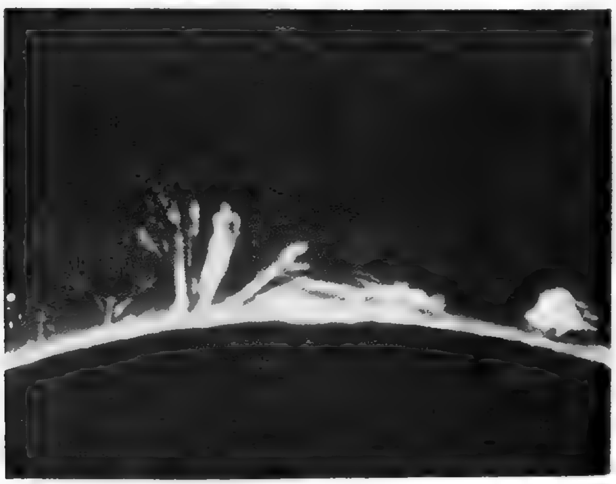
The Solar "Dustbin"
One of the first disposal schemes to come to mind is dumping the waste into the Sun. Unfortunately, this requires the highest

delta-V of any option. To drop a canister into the Sun would require cancelling the Earth's orbital velocity of 18.5 miles per second. Since the Sun has an atmosphere that can be used for braking, this drops to 16.7 mps. This is still almost twice as great as the launch velocities required by interplanetary probes. Even launch from a 115-mile orbit would require a delta-V of 11.86 mps. Solar impact might be accomplished by sending the vehicle on a very close fly-by of Jupiter, which would swing it about into the desired trajectory. Alternatively, a low-thrust ion engine powered by the decaying waste itself might be able to do it (McCollum, 1978). However, it would be worthwhile to consider less difficult options.

Escape from the Solar System

The cheapest option would be to leave the waste in Earth orbit. But such orbits decay in times that are short compared to the lifetime of the waste (McCollum, 1978).

Ejection of waste from the Solar System requires a delta-V of 2.86 mps from a 115-mile orbit (McCollum, 1978). This is much more feasible than the solar impact option, and would certainly serve to get rid of the waste forever. However, we must consider the possibility of mission failure. For example, if the engine shuts off just before the solar escape velocity is reached, the vehicle would be placed in an eccentric (or elongate) orbit with its closest approach to the Sun at the Earth's orbit. It could return to Earth in the future, at any time between a few years and millions of years in the future: depending primarily on how long the engine burned. Sending another vehicle to put it on an acceptable trajectory would prove to be very difficult, especially if a manned vehicle such as the proposed "Space Tug" was used. The Tug would have to carry enough fuel to overtake the waste, slow down for rendezvous, boost the waste to solar escape velocity and return. A delta-V of several mps would be required. An expendable, unmanned tug would need less delta-V, but this also serves to increase the cost. Fortunately, the more extreme the case, the less important is the correcting of the mission. If the engine has burned long enough to put the waste into such an orbit that it will not return for a million years, it is foolish to go to the trouble of boosting it out of the solar system entirely. But if correction is necessary, it should be done as soon as possible. The longer the wait, the greater the chance of losing the waste: once its transmitter stops, location becomes very difficult if not impossible (this applies to all options, not just to solar system escape).



Disposal of nuclear waste in the Sun – an uncertain option. This picture shows solar flares erupting from the surface.

NASA

Stable Interplanetary orbits

The present favoured alternative is injection of the waste into a circular orbit about halfway between the orbit of the Earth and that of Venus. The required delta-V from a 115-mile orbit would be about 2.12 mps. Such an orbit is thought to be stable over periods much longer than the million years or so required (Alternative Technology Strategies, 1978). This has the advantage that the waste would be recoverable.

No massive bodies occupy the region, and a considerable gravitational field would be needed to appreciably alter the orbit of the waste. A direct collision with a small body seems unlikely to alter the orbit much unless the relative velocity is so high that the waste canister would likely be shattered. Passage through a comet presents a quite different picture. In passing through the gaseous coma, the waste would lose velocity relative to the comet. If both had a component of motion in the same direction, with the comet being the faster of the two, then the orbital velocity of the waste would increase. Its new orbit would intersect the old one at its closest approach to the Sun, while its greatest distance from the Sun would be greater than the radius of the old orbit, possibly bringing it near the Earth's orbit. However, since the coma is very thin, this is unlikely to have much of an effect. Further, since neither the comet nor the waste vehicle has an appreciable gravitational field there is no force acting to pull them together, making the chance of collision remote. Since an asteriod presents an even smaller cross-sectional area, the chance of collision per asteroid is even less than the chance of collision per comet.

The only real problem involving mission failure occurs if the injection from the transfer orbit into the storage orbit is not successful. Since we should not wait years or decades for the waste to return to near-Earth space, a deep-space rendezvous capability is required. The required delta-V should be only about 4.5-5 mps; enough to rendezvous, take care of the waste, and return, plus a manoeuvring reserve. However, the duration of such a mission could be several months. A manned Tug would require a life-support system capable of use on missions to Mars or Venus. For this reason, an unmanned vehicle might be preferable.

While other solar orbit options can be imagined, it is hard to conceive of one that offers any significant advantages over the one just described. Ejection into the outer solar system would make recovery and correction in the event of mission failure difficult. Further, the delta-V needed would approach that of the solar system escape option.

The Moon as a disposal site

Closer to home, the Moon should be considered as a waste disposal site. Only a very violent explosion at the disposal site could result in the waste returning to Earth. The small glassy bodies known as tektites are believed by many to be lunar material "splashed" upon the Earth by a volcanic or meteoric impact explosion. It should be easy to avoid putting our waste on the slope of a gigantic volcano; whole large meteoroids should strike the Moon only once in tens of thousands of years. In any case, probably only a small amount of waste would strike the Earth.

There are two lunar disposal options. The waste can be launched so as to impact upon the Moon or it can be soft-landed upon the Moon (McCollum, 1978). Soft-landing is more expensive, but it offers the option of recovery in the future.

The hard impact option requires a delta-V of 2.01 mps from a 115-mile orbit (McCollum, 1978). The waste would strike the Moon at the lunar escape velocity of 1.5 mps. If the waste vehicle has a mass of a few tons, then the explosion at impact would be on the order of that due to a few tons of TNT. All waste should be dumped in the same area, so as not to interfere with scientific exploration of the rest of the Moon (McCollum, 1978).

Soft-landing upon the Moon would require an additional

One of the "better" options – disposal of waste on the Moon. This picture obtained by Lunar Orbiter 5 shows the crater Tycho, 80 km (50 miles) across, named after the 16th century Danish astronomer.

WHAT IS YOUR OPINION?

We recognise that this article is likely to stir controversy. Can we accept the extra hazard that might be caused by possible launch mishaps with payloads of nuclear waste? And what of the ethics of "contaminating" other parts of the Solar System and outer space? We shall be pleased to consider letters on this topic for possible publication. Ed.

delta-V of 1.5 mps, for a total of 3.51 mps. While this would be a more expensive option, it would not interfere with lunar research unless the engine failed to fire on descent, thus switching the mission over to the hard impact option.

There seems to be little advantage in sending the waste to some other celestial body. The Moon is a very safe repository, and any other destination would require a higher delta-V.

The Lunar Trojan Points

Yet another option is placing the waste in one of the lunar trojan points, 60° ahead and behind the Moon in its orbit. The Earth, Moon and each point lie at the vertices of an equilateral triangle, which has sides the length of the radius of the Moon's orbit. Due to perturbations, there is an extended region about each point in which bodies can move in stable orbits about the point (O'Neill, 1977). Since there are two such regions, one could be used for high-level waste storage, with the other left for possible future space colonies (O'Neill, 1975). The necessary delta-V is the same as that for the lunar impact option, 2.01 mps. But this procedure gives us the option of recovery. This could prove to be the best option yet considered, if orbital stability can be assumed for the desired million years or so.

Mission failure in any of these last three options presents almost identical problems. An early engine shut-off would leave the vehicle in an eccentric orbit with its closest approach to Earth at 115 miles. The Tug should be capable of a delta-V of 4-4.5 mps if it must return. However, since the duration of the mission should not exceed 8-10 days, no elaborate life-support system would be required for a manned vehicle.

It is hard to determine the absolute economics of any of these options, even barring radical technological innovations. The necessary hardware (Shuttle, Tug and waste booster) have many applications besides the disposal of nuclear waste. Development of the entire system solely for disposal of nuclear wastes would present much greater costs than a disposal programme using "off-the-shelf hardware." The actual cost can therefore be considered a function of the vigour of the entire space programme.

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SATELLITE DIGEST - 136

A monthly listing of all known artificial satellites and spacecraft by Robert D. Christy. A detailed explanation of the information presented can be found in the January, 1979 issue, p. 41.

Continued from March issue

Name, designation and object number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch site, launch vehicle and payload/launch origin
DSCS II (13) 1979-98A 11621	1979 Nov 21.09 indefinite	Cylinder 550?	1.8 long 2.7 dia	35594	35789	2.42	1431.1	ETR Titan 3C DoD/USAF (1)
DSCS II (14) 1979-98B 11622	1979 Nov 21.09 indefinite	Cylinder 550?	1.8 long 2.7 dia	35792	36357	2.41	1450.7	ETR Titan 3C DoD/USAF (1)
Cosmos 1145 1979-99A 11629	1979 Nov 27.42 60 years?	Cylinder+panels? 2500?	5 long? 1.5 dia?	623	634	81.21	97.33	Plesetsk A-1 USSR/USSR (2)
Cosmos 1146 1979-100A 11632	1979 Dec 5.44 2 years?	Cylinder? 1000?	3 long? 1.5 dia?	444	494	65.85	94.00	Plesetsk C-1 USSR/USSR
RCA SATCOM 1979-101A 11635	1979 Dec 7.066 indefinite	Box+antennae +panels 895	1.17 high 1.62 across 1.20 deep	162	35798	23.85	630.0	ETR Delta RCA/NASA (3)
Cosmos 1147 1979-102A 11638	1979 Dec 12.52	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	195 332 352	380 388 418	72.86 72.88 72.87	90.31 91.78 92.29	Plesetsk A-2 USSR/USSR (4)
Soyuz T (1) 1979 103A	1979 Dec 16.513	Sphere+cone- cylinder+2 panels? 7000?	8 long? 2.2 dia	195 335	215 360	51.6 51.6	88.5 91.4	Tyuratam A-2 USSR/USSR (5)

Supplementary notes:
(1) Pair of US military communications satellites, destined for geostationary orbit.
(2) Possibly an electronic ferret.
(3) US domestic communications satellite operated by the Radio Corporation of America, the satellite was "lost" at the time of apogee motor firing as injection into geostationary orbit was due.
(4) Orbital data are at 1979 Dec 12.5, Dec 13.4 and Dec 15.3.
(5) Test flight of a recoverable transport ship for use with orbiting laboratories. Soyuz T docked with Salyut 6 about 1979 Dec 19.65. Previous tests of Soyuz T systems were carried out as Cosmos 1001 (1978-36A) and Cosmos 1074 (1979-8A). Orbital data are approximate and are for 1979 Dec 16 and Dec 20.

Amendments:
1979-73A, Cosmos 1120 was launched from Tyuratam, not Plesetsk.
1979-97A, Cosmos 1144 was recovered 1979 Dec 4, lifetime 32 days.

IF YOU ARE ELIGIBLE FOR FELLOW, THEN BECOME ONE.
The Society relies heavily upon its Fellows. This is a grade which indicates to the world, more than anything else, the Society's technical status. Fellows are elected only if their backgrounds, experience and qualifications all match up to rigorous standards. If you are eligible why not add that extra distinction, FBIS, after your name?

The conduct of the Society falls heavily upon the shoulders of Fellows, not only in its day-to-day affairs but in providing the technical content for its magazines, specialized symposia, study courses and projects.

Fellows are constantly being sought to assist the Society in a variety of ways. If you are really eligible for Fellow, yet actually hold a lower grade, please do make the transfer now. Indicate to the world, and to the Society itself, that you have met the qualification requirements and that you are ready and able to undertake commitments to foster the work of the Society and to further its aims in every way.

Please apply to the Executive Secretary for a Transfer Form at once.

CORRESPONDENCE

Blue Streak Hardware

Sir, To update the information in my article "Space at East Fortune" (*Spaceflight*, November 1979), I would like to make two points regarding the locations of Blue Streak rockets.

When the Europa programme was cancelled in 1973, two Blue Streak rockets were left in Kourou: F12 and the research vehicle. After a number of years the European Space Agency sold the unwanted hardware for £2,300 to Mr. Stephen Gay, a Swiss businessman now living in Cayenne, French Guiana. He stripped them down and is now trying to sell the components as scrap.

F15 has been moved from the Deutsches Museum to the military airfield at Erding, 30 km North-East of Munich. It will be back on public display in about 3 years time when a new astronautics section of the Deutsches Museum is completed.

ALAN LAWRIE,
Cheltenham, Gloucestershire.

"Living in Space Stations"

Sir, Since *Spaceflight* arrives with an approximate delay of two months in Mexico City I only recently discovered that you published my second interview with Dr. Joseph P. Kerwin ("Living in Space Stations" *Spaceflight*, June 1979).

I am happy to see that my efforts reach the right people but would for the same reason also like to inform you about a typographical error on page 273 that makes no technical sense: instead of "zero-g stations and the Moon" *Spaceflight* published "zero-g stations on the Moon".

Congratulations on your new headquarters!

MARIO MUTSCHLECHNER,
Mexico City, Mexico

We apologise to Mr. Mutschlechner for this slip. Ed.

Headquarters Security

Sir, As in the future many meetings, lectures, etc., will be held in the meetings room of 27/29 South Lambeth Road, I would like to put forward the idea of possible membership cards/identity badges that may be pinned to the lapel or pocket.

Please do not think that I am suggesting that our fellow members are not to be trusted, but as you point out in the progress report of the new HQ, security is all important. Keep up the great work.

STEPHEN J. HOWLETT,
Dagenham, Essex.

Moonflowers at HQ?

Sir, I was very moved by the letter from your neighbour, Margaret A. Walsh (*Spaceflight*, August-September 1979, p. 384) and I hope you can satisfy both her curiosity and her desire for window boxes. To help the latter, I am enclosing £1 towards the contents of a window box – Moonflowers perhaps, or a Venus fly-trap?

MIRIAM MASON (Mrs),
Outwood, Nr. Redhill, Surrey.

To the Executive Secretary

Sir, Many thanks for the two films which I arranged for my school to borrow last month. The films, along with a short talk I gave, were for a 10th anniversary celebration of Apollo 11 in the weekly General Studies lecture and seemed to go down quite well.

Thanks also to everyone for a flying visit I made to the new HQ in July. Living in the "provinces" as I do, visits to London are rarieties. So I took the opportunity to call after attending a 6th form conference at UCL and despite arriving at an inconvenient moment when a number of meetings were in progress, I was shown round the building. Seeing what has been achieved with the resources available I am more certain than ever that I belong to a Society to be proud of!

Keep up the great work!

JED H. WHITTINGHAM, (Student Member),
Oakengates, Telford, Salop.

Monitoring the Earth/Space Environment

Sir, As subscribers to your magazine, we would like to introduce our organization and services. It occurred to us that your publication reaches a variety of readers who may find our services useful, but are not aware of our existence. Allow me to tell you a little about our operation.

The National Oceanic and Atmospheric Administration (NOAA) is a branch of the US Department of Commerce. NOAA operates several laboratories of which the Environmental Research Laboratory (ERL) is one. Located in Boulder, Colorado, ERL, as its name implies, is concerned with the environment. One segment of the environment, the solar terrestrial environment, is the concern of the section which I would like to introduce, The Space Environment Services Center (SESC).

The SESC has been fully operational since 1969. Its function is to monitor, collect, analyze and predict solar and geophysical parameters. To fulfill this obligation, the SESC operates a telescope, radios and other monitoring equipment in Boulder. It has access to data from several satellites and is cooperative with observatories around the world. This insures a continuous flow of solar geophysical data into the SESC computers on a Real-Time basis.

Once per day, the SESC issues a comprehensive forecast consisting of probabilities of flare occurrence, the 10.7 cm radio flux, proton event probabilities and the geomagnetic field A-index. A weekly forecast is also issued. The weekly report gives a 27-day forecast of solar and geomagnetic activity in general terms as well as synopsis and tabulation of what has occurred during the past week.

Another service offered by the SESC is alert notification. Those activities that are impacted by solar activity can be notified when their critical thresholds have been reached.

If you feel, as we do, that you would be doing your subscribers a service by informing them of our service, please feel free to publish our address and telephone number. Our services are free. Some types of communication cost are at customer expense.

Space Environment Services Center
Room 2010, 325 Broadway, Boulder,
Colorado 80303
Phone: 499-1000, extension 3171

WILLIAM E. FLOWERS,
Space Scientist,
Space Environment Services Center,
US Department of Commerce,
National Oceanic and Atmospheric Administration
Environmental Research Laboratories, Boulder,
Colorado 80303, USA.

Naming the Apollo 13 CM

Sir, In the July 1979 issue Mr. Philip W. Snowdon queried the name chosen for the Apollo 13 command module.

After the crew named the lunar module *Aquarius*, they turned to a suitable name for the command module. Many

ideas were considered – and most of the names were those of gods in both Greek and Roman mythology. The final (and apparently unchanged) choice fell on *Odyssey*. No thought was given to naming the command module after a constellation so Mr. Snowdon's doubts about the module originally being called *Auriga* are substantiated.

My source for the above information is Captain James A. Lovell, commander of the mission.

H. J. P. ARNOLD,
Havant, Hampshire.

BIS – British Institute of Space?

Sir, Regarding the subject of a name change, many people seem to refer to the Society by its initials BIS.

Why not change the name to the British Institute of Space? The initials remain the same and it seems a more accurate description of the interests and activities of the Society, especially when schemes like Daedalus and the study course on the origins of the Universe are considered.

TONY FRANKLIN,
Croydon, Surrey.

An earlier suggestion was: The British Institute of Spaceflight. Ed.

Soyuz Training Capsule?

Sir, Several lines of my letter [1] concerning a possible Zond photograph were omitted in publication, leading to some loss in clarity. The correct second paragraph reads as follows:

A rather intriguing photograph appeared in *Spaceflight* in early 1975 as part of an article outlining the ASTP mission [3]. It is said to show Valeri Kubasov "in the Soyuz training capsule", and the spacecraft shown does indeed resemble a Soyuz DM at first glance. However, this identification is certainly in error, as can be seen by comparing any photograph of an actual Soyuz DM main instrument panel. (All known Soyuz variants to date, broadly divisible into Soyuz 3-11, 12-present (excluding 16 and 19), and ASTP have had very similar main control and display panels. [4] contains excellent prints of the ASTP Soyuz, and [5] gives plates and drawings of the Soyuz 3-11 type panels.)

TREVOR WILLIAMS,
West Kensington, London.

REFERENCE

1. Trevor Williams, "Correspondence", *Spaceflight*, Nov. 1979, p. 478.

Pick-a-back Scientific Capsule

Sir, The purpose of the squat cylindrical device on the nose of the Soviet Vostok biosatellite has never been explained in print. I have always suspected it could be the pick-a-back scientific capsule periodically carried on Cosmos reconaissance satellites (see *Soviet Space Programs 1971-75*, Shelton, p. 116). Some new information I have come across strengthens my argument. In the abstract for a recent scientific paper (on NASA microfiche A79-41707, document "Life Sciences & Space Research XVII", Proceedings of the Open Meeting of the Working Group on Space Biology May 29–June 10, 1978 and Symposium on Gravitational Physiology, Innsbruck, Austria June 2-3, 1978), it states that the biosatellite Cosmos 782 carried instruments for studying the LET (Linear Energy Transfer) spectra of galactic cosmic rays. Unless there was room inside the re-entry sphere (photographs show it crowded with the biological research apparatus), I believe the cosmic ray instruments would be best carried outside the re-entry sphere in a separate container. This would be the squat cylindrical object emblazoned with the flags of the participating nations.

It has also come to my attention that the Soviets are now referring to their Earth-resources Cosmos spacecraft by the name of "Nature" (Priroda) in *Pravda's* TASS dispatches. Cosmos 1115 (launched on July 13, 1979), Cosmos 1118 (July 27), Cosmos 1119 (Aug. 3) and Cosmos 1122 (Aug. 17) are the recent Earth-resources spacecraft identified in *Aviation Week* (AW&ST, Aug. 13 & 20, 1979) that are called "Nature" in *Pravda*. These spacecraft fly in 81.4° inclination orbits.

JOEL W. POWELL,
Calgary, Alberta

Society Name

Sir, As regards the old question of the Society title, surely we should aim to change it to "The Interplanetary Society" having made it just that!

P. CHANT, Lieutenant Commander, RN.
HMS Churchill.

Bulgaria in Space

Sir, I read with great interest your magazine *Spaceflight*. We Bulgarians are proud of our country's first cosmonaut Lieutenant-Colonel engineer Georgi Ivanov. He is a very good man and I and many Bulgarians will be very pleased if you would print something about him in your magazine.

MIROSLAW MARKOV,
Pilot engineer B.Sc., First Lieutenant,
Sofia, Bulgaria.

Lieutenant Markov was kind enough to enclose a short biography of Georgi Ivanov together with photographs. However, we had already taken steps to include a biography of the Bulgarian cosmonaut in our February 1980 issue. We used one of Lieutenant Markov's photos as an illustration. Ed.

Living in Space Colonies

Sir, In all the articles on space colonies there is one factor which, it seems to me, has been insufficiently considered. Here on this Earth there are (still) vast areas of terrestrial and oceanic wilderness. Even if we never go there, it is comforting to know that they are there. I suspect that there is more than a hint of Sir Francis Chichester in a good many of us. From time to time we find it almost a necessity to head for the open spaces where we can commune with nature and, even if only for a short period, become self-reliant. What will be the effect on the space colonist, living in a relatively restricted area, and with little prospect of ever "getting away from it all"?

It would appear that the only human beings remotely qualified to live in such a restricted environment as a Space Colony are monks and nuns accustomed to living in a totally enclosed community. Yet even there they are in touch with nature. What kind of human beings will they be who have no real contact with the natural beauty which humanity has known for all its existence? Few of us, however objectively scientific we may claim to be, are immune to the deep spiritual pleasure of walking on hills which we know have been there for thousands if not millions of years; of watching birds which have flown thousands of miles to reach us; of strolling through age old woods (I could go on).

Whatever attempts may be made to reproduce Earthlike conditions on a Space Colony, the fact remains that life there would be little better than a kind of bland Devil's Island. Who would be willing to condemn themselves and their children to such an existence?

Of course it is conceivable (some would say certain) that man must leave the Earth in order to survive at all; that if he does not, *homo sapiens* will become extinct. Does that really matter?

JOHN ALLISON,
Warley, West Midlands

JOHN CHAPMAN

Dr. John Chapman, the father of Canada's space programme, died in Vancouver on 28 September 1979. He had been the driving force behind Canada's satellite programme for the last 20 years, and at the time of his death was assistant deputy minister (space programs) of the Department of Communications, writes Gerald L. Borrowman.

Communications Minister David MacDonald said, "Canada has lost an extraordinary individual. Dr. Chapman played a major role in virtually every space activity in Canada. Canada's space programme is where it is today to a very large extent because of his efforts."

Dr. Chapman initiated and guided Canada's entry into space by way of the Alouette and ISIS satellites, which gained Canada international reputation in space science. In 1967, he was appointed chairman of a government task force to study and advise on satellite communications in Canada. The report, published in 1968, was officially entitled, "A Domestic Satellite Communication System for Canada", but became widely known as "The Chapman Report".

Telesat Canada, the domestic satellite corporation, was established a year later as a result of the recommendations in the report.

Dr. Chapman was also a prime mover behind Canada's communications technology satellite (CTS) programme which started in 1971-72. The CTS programme resulted in the launch in January 1976 of Hermes, the eighth Canadian satellite and the first geosynchronous communications satellite to operate in the 14/12 GHz frequency band. When launched, it was the world's most powerful communications satellite and was a forerunner of the direct-to-home broadcast satellite.

"One of Dr. Chapman's current enthusiasms was the idea of providing direct-to-home TV by satellite to people in remote and rural areas of Canada. He saw this prospect back in 1971, a prospect which is close to realization with the inauguration in Ontario only three days ago of the first direct-to-home satellite broadcast service," said Mr. MacDonald.

Dr. Chapman had led a successful government-industry mission to Australia in August, which demonstrated Canadian industrial and scientific capabilities in the field of high-powered broadcasting satellites and small, low-cost Earth stations to the Australians, who are considering setting up a system, possibly similar to that of Telesat Canada.

He was due to be presented in Toronto with the 1979 McNaughton Gold Medal Award of the Institute of Electrical and Electronics Engineers, in recognition of his "outstanding contributions as a professional engineer to the development of Canadian engineering excellence. . . ."

Dr. Chapman had pushed for the development of a prime contracting capability in Canada for the construction of commercial satellites, an idea which came to fruition a few months earlier when Telesat Canada announced the award of the contract for the Anik D satellites to Spar Aerospace Ltd. of Toronto.

Dr. Chapman was born in London, Ontario, in 1921, and obtained a B.Sc. in Radio Physics at the University of Western Ontario in 1948, after interrupting his academic career to serve in the Royal Canadian Air Force during World War II. The following year he obtained a Masters degree in Physics at McGill University, and two years later, a Doctorate in Physics at the same university.

Dr. Chapman won a number of scholarships at both universities, and was the recipient of a National Research Council Fellowship during 1950.

From 1940-1945, he served overseas with the RCAF as a specialist radar officer in Britain and West Africa. He retired from the RCAF at the end of the war with the rank of Flight Lieutenant.

In 1951, he was named a senior scientist at the Defence Research Telecommunications Establishment (DRTE) at Shirley Bay, on the outskirts of Ottawa, where he was in charge of the Ionospheric Research Station. He was later named Superintendent of the Communications Wing. In 1959, he was appointed Deputy Director General of DRTE.

He was Canadian Co-ordinator for the joint Defence Research Board (DRB)/US National Aeronautics and Space Administration Alouette-ISIS ionosphere sounding satellite projects, and received numerous awards for his contributions to space research.

Early in July 1968, after spending a year in Québec City participating in a Public Service Bicultural Development Program, he returned to Ottawa to assume the Headquarters position of Deputy Chairman (Scientific) DRB. Shortly afterwards, he was loaned to the office of the Postmaster General to assist in planning a new government department to be called the Communications Department.

He wrote many scientific papers as a result of fundamental research activities, including a number presented before learned societies. In 1956, he attended the 16th course at the Joint Services Staff College in the United Kingdom. He was a fellow of the Institute of Electrical and Electronics Engineers, the Canadian Aeronautics and Space Institute, as well as past president of the Academy of Science of the Royal Society of Canada. Dr. Chapman was a member of the Canadian Association of Physicists and the Association of Professional Engineers of Ontario.

In January 1970, Dr. Chapman was appointed Assistant Deputy Minister for Research with the Department of Communications. In 1974, he was appointed Assistant Deputy Minister, Space Programs, in the Department of Communications.

From 1972, Dr. Chapman was the Chairman of the Interdepartmental Committee on Space which is responsible for the coordination of Canadian space activities.

Dr. Chapman is survived by his wife and five children.

NEW INTERNATIONAL AGREEMENT

In Paris recently a ceremony was held whereby the members of the International Satellite Consortium COSMOS agreed to extend their operating agreement to co-operate in the European space programme for a further period of three years, writes N. E. Steggall. This agreement was signed by the senior executives of each of the consortium's members:

Marconi Space and Defence Systems Limited – UK.
Etudes Techniques et Constructions Aerospatiales (ETCS) – Belgium.
Societe National Industrielle Aerospatiale (SNIAS) – France.
Societe Anonyme de Telecommunications (SAT) – France.
Messerschmitt-Bolkow-Blohm GmbH (MBB) – FDR.
Construcciones Aeronauticas S.A. (CASA) – Spain.
Selenia Spa – Italy.

Present at the ceremony was Mr. Roy Gibson, Director-General of the European Space Agency (ESA), who emphasised the importance of Europe maintaining an active role in future space programmes and who wished the COSMOS consortium every success during its next three years. The first COSMOS agreement was established in 1971 and probably the most celebrated success of its lifetime to date has been the Meteosat meteorological satellite. ESA's EXOSAT, which is due for launch in 1981, is amongst its current activities, and in conjunction with the Ford Aeronautics Communications Corporation, the provision of the first eight spacecraft so far ordered for the Intelsat 5 programme.

CALL FOR PAPERS

	17TH EUROPEAN SPACE SYMPOSIUM
Venue:	Royal Commonwealth Society, Northumberland Avenue, London, WC2.
Dates:	4-6 June, 1980 (All Day).
Theme:	**SPACE IN THE 1980's AND BEYOND**
Technical Sessions:	(a) "Near Future" Projects (for the 1980's and 1990's) (b) Projects for the 21st Century (c) A Developing Role for the European Space Programme (d) The Roles of Industry and Government.
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Hotel Accommodation and Registration:	Details on request.
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Further Information:	Apply to the Executive Secretary, the British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Telephone: 01-735 3160.

THE BRITISH INTERPLANETARY SOCIETY 27/29 SOUTH LAMBETH ROAD, LONDON SW8 1SZ

NEW MEMBERSHIP DRIVE

WANTED: 3500 NEW MEMBERS

In terms of numbers of members, publications and other activities, 1979 saw a record progress for our Society. But this is no time to pause for self-congratulation: as fast as the Society grows, the worldwide involvement in space and astronautics is growing even faster.

It is vital that we secure thousands of new members, particularly those with technical backgrounds, to add to our Status and to our ability to contribute to these exciting new space endeavours, to expand the Society's work, influence its future, and help it financially.

The more income we receive, the wider we can spread overheads and so hold subscriptions to a minimum.

Our most promising source of new members has been, and still is - YOU. This is why we now appeal to every member to act immediately and make a special effort **to introduce at least one new member without delay.**

We can help from HQ by sending application forms and specimen copies of SPACEFLIGHT, on request, either to yourself or to persons whose names and addresses you forward to us.

We are relying on you to discover some of the thousands of new members that we need. Think "BIS". Help to swell our ranks and keep subscriptions to a minimum.

We are counting on your support.

1980 SUBSCRIPTIONS

Subscription rates for 1980 are detailed below:

	Sterling	*US Dollars*
Members (under 21)	£11.00	$25.00
Members (21 and over)	£12.00	$27.00
Senior Members	£12.50	$28.00
Associate Fellows	£13.00	$29.00
Fellows	£13.50	$30.00

The above fees include the receipt of *one* of the Society's publications. A further £13.00 ($29.00) should be added where members wish to receive *both* publications.

To avoid the expense of collecting small balances, members who remit by Banker's Order are urged to ensure that the amounts transferred are the current rates.

Remittances may be sent now to:-

The British Interplanetary Society,
27/29 South Lambeth Road, London, SW8 1SZ, England.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 27/29 South Lambeth Road, London SW8 1SZ Tel: 01-735 3160

Correspondence and manuscripts intended for publication should be addressed to the Editor, 27/29 South Lambeth Road, London SW8 1SZ.

Opinions in signed articles are those of contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Lecture
Title: **THE DEVELOPMENT OF THE BLUE STREAK ROCKET**
by C. H. Martin

To be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ on **9 April 1980**, 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Lecture
Title: **JUSTIFICATION OF SPACE PROJECT PROPOSALS**
by E. G. D. Andrews

To be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ on **23 April 1980**. 7-9 p.m.

"In the design of proposals for a major project, especially one contemplating space or interplanetary colonization, it may be necessary to take into account a wider range of constraints than can be properly organized by any single human mind unaided. The speaker has introduced a formal procedure (PADIS) based on the logic of the natural design process, which identifies the sequence in which the design investigations should be carried out to minimize reiteration, and permit effective collaboration in design to be provided by all who have relevant knowledge, without interfering with the conceptual tasks. The design of a lunar village is used for the purposes of illustration".

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Film Show
Theme: **APOLLO HEYDAY**

To be held in the Golovine Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **7 May 1980**, 7-9 p.m.

The programme will be as follows:
Doorway to Tomorrow (1967)
Spaceport USA (1970)
The World Was There (1976)
The Time of the Apollo (1975)

Admission will be by ticket only. Members should apply in good time, enclosing a reply-paid envelope. Should the number of requests for tickets exceed the accommodation available, the programme will be repeated and later participants notified accordingly.

Lecture
Title: **PLANET VENUS: 1980**
by John Bury

A lecture with a short discussion on recent experimental results and their interpretation with regard to the planet Venus to be held in the Golovine Conference Room, Society's HQ, 27/29 South Lambeth Road, London SW8 1SZ on **14 May 1980**. 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

17th European Space Symposium
Theme: **ASTRONAUTICS IN THE 1980s AND BEYOND**

A three-day meeting to he held at the Royal Commonwealth Society, London W.C.2 from 4-6 June 1980, sponsored by the BIS, AAAS, AIDAA and DGLR and co-sponsored by EUROSPACE.

Offers of papers are invited. Please contact the Executive Secretary for further information. Registration is necessary. Copies of the programme will be available in due course.

SOLAR ECLIPSE JULY 31ST 1981

The Southern California Branch is interested in making up a small group expedition to view the solar eclipse on 31 July 1981. A tour of about three weeks in duration is envisaged, flying from Los Angeles with connections from the United Kingdom, and continuing via Ulan Bator, Ulan Uda to the vicinity of Novosibirsk for the viewing, thence with return to Warsaw via Soviet Georgia, for the flight back to the UK/USA.

Arrangements will be in the hands of Mr. R. V. Frampton, Mail Stop 264-519, Jet Propulsion Laboratory, Pasadena, California 91103, USA. Members interested should contact Mr. Frampton for inclusion in the preliminary list of participants.

The total cost will be dependent upon the number participating.

Visit
SRC APPLETON LABORATORY

Arrangements have been made for a small party of members to visit the SRC Appleton Laboratory at Ditton Park, Slough, together with a visit to their out-station, the Satellite Signal Reception Centre at Winkfield, on **10 September 1980** (all day).

Registration is necessary. Members interested in receiving further information must apply to the Executive Secretary, enclosing a reply-paid envelope, in good time.

35TH ANNUAL GENERAL MEETING

The 35th Annual General Meeting of the Society will be held in the Tudor Room, Caxton Hall, Caxton Street, London S.W.1 on **18 September 1980**, 7.00 p.m.

A detailed Agenda will appear in *Spaceflight* in due course.

Nominations are invited for election to the Council. Forms can be obtained from the Executive Secretary. These should be completed and returned not later than 25 June 1980.

Should the number of Nominations exceed the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members.

31ST IAF CONGRESS

The 31st Congress of the International Astronautical Federation will be held in the Takanawa Prince Hotel, Takanawa, Minato-ku, Tokyo, Japan from **21–28 September 1980.**

Members of the Society intending to present papers are asked to notify Dr. L. R. Shepherd, Chairman of the BIS International Liaison Committee at Society H.Q. as soon as practicable.

Lecture
Title: **SPACE REVIEW – 1980**
by P. S. Clark

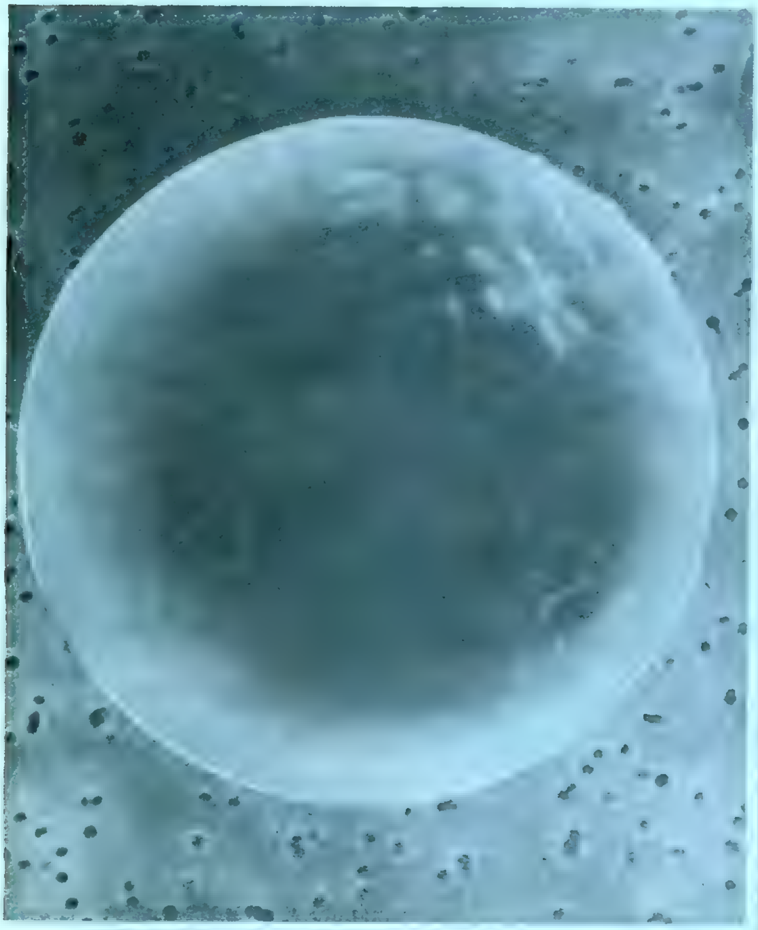
A review of space activities throughout the world which have taken place during the past twelve months, to be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ, on **8 October 1980**, 7-9 p.m.

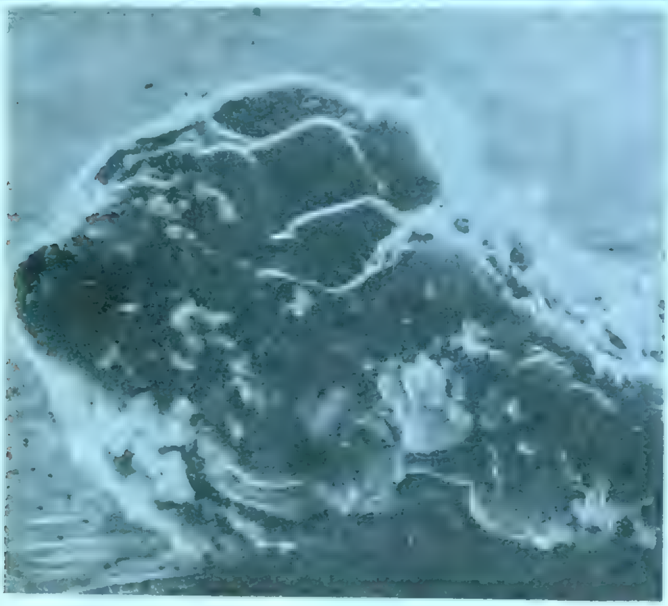
Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published for The British Interplanetary Society Ltd., (No. 402498) by Space Educational Aids Ltd., (No. 741211). Registered Office: 27/29 South Lambeth Road, London, SW8 1SZ, England.

ISSN 0038-6340

SPACEFLIGHT





VOLUME 22 NO.5 MAY 1980

Published by
The British Interplanetary Society

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Editor:
Kenneth W. Gatland, FRAS, FBIS

CONTENTS

COVER

COMET DUST? Tiny particles of dust that may have come from passing comets have been analysed by a group of American scientists working for NASA. The scientists collected the dust by attaching sticky plates to a U-2 aircraft which was flown to a height of more than 12 miles (19.3 km). Magnified about 15,000 times by a scanning electron microscope, the particles show distinctive characteristics. The rarer type, *top left*, is hard and round and apparently formed by some kind of melting process that took place in Earth's atmosphere or in outer space. The more common type, *below*, is "fluffy" and made up of as many as a million separate grains of different minerals. *Right*, profile of a comet moving close to the Sun. Commenting on the findings, Dr. Bevan M. French said "about half a ton of extraterrestrial dust falls to Earth each day, and much of it may have come out of comets or new kinds of fragile meteoroids that don't survive to reach the ground." (see *Spaceflight*, March 1980, p. 135).

NASA

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 NO.5 MAY 1980 *Published 15 April 1980*

The US Perspective

The top US space official proudly informed the Congress that more nations are participating in space related activities while quietly noting that NASA's once exclusive lead in boost power faces more competition. "To stay ahead we must maintain a vigorous programme," Administrator Robert Frosch told Congress while urging favourable action on the agency's $5,700 million budget for 1981.

Europe's Space Agency is participating in Spacelab, the multi-purpose facility designed for Shuttle launch and three other current projects:

- *International Solar-Polar Mission*, twin launches in 1983, spacecraft simultaneously travelling over opposite poles of the Sun, having first flown by Jupiter and using the planet's gravitational force to swing them out of the ecliptic for a first look at the Sun's heliosphere from that vantage point. The US will spend $82.6 million on the joint effort in 1981.
- *Space Telescope*, "keystone of the decade," Frosch stated, for Shuttle launch in 1983, entering peak design activity in 1981, for which NASA requested $119.3 million in 1981. The agency plans a permanent Space Telescope Science Institute to manage the observatory.
- *International Ultraviolet Explorer*, launch 1981.

The German Federal Republic will provide an important element of the Galileo orbiter postponed from 1982 until 1984 because of Shuttle delays. NASA will employ the inertial upper stage for separate launches of the orbiter and probe. The mission remains unchanged: to study the Jovian atmosphere dynamics, satellites and magnetosphere.

"The orbiter should achieve 11 encounters with the Galilean satellites, mapping their surfaces more completely than possible with Voyager," Frosch observed. "During its 20-month orbital tour the orbiter will map the magnetosphere of Jupiter and obtain data on the dynamics of its atmosphere."

The United Kingdom and Netherlands are providing spacecraft and ground support system for an Infrared Astronomical Satellite soon to enter system integration and test.

Other nations displaying keener interest in space are "attractive potential partners on major projects such as planetary exploration which might otherwise be impossible for NASA" to finance, Frosch added.

He told Congress that China will shortly purchase a Landsat D ground station from US contractors and join eight other nations receiving Earth sensing data. At least six more countries are expected to follow suit by the mid-1980s.

France is building a similar spacecraft for 1984 launch while India, Japan and the European Space Agency are in various stages of planning. The US is discussing with each opportunities for compatibility and complementary efforts.

But even as US boost capabilities are strained by Shuttle delays, Frosch saw the likelihood of competition for launch assignments. ESA's Ariane booster matches the US Centaur in payload, Japan is developing the N vehicle in the Delta class and India has tested SLV-3 of the Scout class.

Cost will undoubtedly influence users enjoying the choice of boosters later in the decade. – Gordon L. Harris.

MILESTONES

January 1980

30 NASA announces that it has signed a $183,960,000 contract with the European Space Agency calling for manufacture and delivery in 1984 of a second Spacelab.

February

1 A planned 560 sec firing of the Space Shuttle three main engines at the National Space Technology Laboratories is terminated after 4.6 sec. Reason for the automatic shutdown is a higher than nominal temperature indication.

7 US Air Force launches KH-11 reconnaissance satellite by Titan IIID from Vandenberg AFB, California. The satellite entered an initial orbit of 220 x 498 km inclined at 97 deg to the equator; later the orbit was changed by a power manoeuvre to 304 x 469 km x 97.05 deg. Unlike photo-reconnais-

[Continued on page 192

POLAND IN THE INTERCOSMOS PROGRAMME

By Dr. Olgierd Wolczek*

Last year the Polish Astronautical Society celebrated the 25th anniversary of its birth. It is therefore with great pleasure that we publish an article by Dr. Olgierd Wolczek, a distinguished friend and colleague of long-standing through our mutual association in the International Astronautical Federation.

Introduction

Outer space research has ceased to be the exclusive privilege of the world's most powerful states – the Soviet Union and the United States - but many medium and small states already are taking a hand in it. Astronautics calls for the most perfect methods of study and the most advanced scientific apparatus and technology. It is an exceptional stimulation of science, technology, and industry at large, and, therefore, a particular factor of economic growth.

Poland has joined in space exploration, pinning on it, as on nuclear technology, much hope for her scientific, technological and consequently, economic development.

Intercosmos Programme

Understandably, Poland cannot afford by herself to contribute to the space programme a share equalling that of the Soviet Union. Therefore, she has acceded to the "Intercosmos" organization established by the socialist countries with joint cooperation in space research in mind.

An appropriate founding agreement signed in 1967 was followed by a new cooperation agreement in 1976. Under that accord Poland contributes her astronauts to joint manned space flights and to joint manned orbital stations.

The Polish space programme received a fresh organizational boost when the groups of specialists, which used to be attached to individual schools of higher learning, were concentrated in 1977 to form the Polish Academy of Sciences Space Research Centre, under Professor Stanislaw Grzedzielski. The Centre is concerned with space physics, solar physics, satellite geodesy, physics of the atmosphere, astrodynamics for orbit science, etc. On the other hand, research in space biology and medicine is the responsibility of the Military Institute of Aviation Medicine, directed by Professor Stanislaw Baranski, as well as of some sections of the Polish Academy of Sciences (PAS).

A relevant role in developing space research and scientific contacts in Poland and abroad is played by the Polish Astronautical Society, established in 1954, three years before the world's first artificial satellite "Sputnik 1" was launched.

All outer space studies are supervised by the PAS Committee for Space Research, presided over by Professor Jan Rychlewski, the Secretary of the 3rd Department of the Polish Academy of Sciences.

Space physics

In our outer space exploration we use Soviet-launched "Cosmos" and "Intercosmos" satellites. As part of the "Intercosmos 6" programme, launched in 1972, Poland carried out her first high-energy physics tests in space. Installed on board the satellite were the emulsion block and an ionization calorimeter designed to register and explore the spectra of the primary cosmic radiation consisting of atomic nuclei of all elements. The Polish experiments, apart from a close study of the phenomenon, threw some light on the behaviour of high-energy particles.

* *Vice-President, Polish Astronautical Society.*

Polish scientists are making major contributions to various research activities within the Intercosmos programme. Here three of their number relax for a moment during electronic compatibility tests related to the satellite Intercosmos 19.

At the cosmodrome, *left to right*, Arcadius Kiraga, Krzysztof Nowak and Slowomir Aliszkiewicz pose for the photographer alongside the launch vehicle.

A series of experiments were carried out by scientists studying solar phenomena. Heliophysicists from Wroclaw explored the part of the solar radiation which is absorbed by the atmosphere before reaching the Earth's surface. They employed for this purpose devices of their own design: special-purpose cameras and spectrometers, serving to record X-rays, as well as instruments for studying the ultra-violet solar radiation and, thereby, the peaks of solar activity. These experiments were conducted with the help of Soviet-made geophysical rockets of the "Vertikal" type, launched to high altitudes.

The Sun's explosive radio rays were studied by means of the Interkosmos satellite "Kopernik 500", launched into space to mark the 500th anniversary of the birth of Nicholaus Copernicus. The observations were made with the help of a special device developed jointly by specialists from Torun University and from the Aviation Institute in Warsaw. The device, called a "radio rays spectograph", was later used to study phenomena occurring in the ionosphere.

Geodesy

In the domain of satellite geodesy Poland has been carrying out observations of the orbits of artificial satellites. The observations are made by the Agricultural Academy in Olsztyn, the Adam Mickiewicz Astronomical Observatory in Poznan, and the Institute of Geophysics in Borowiec. The observations concern the influence of the Earth's gravitational field on the satellite orbits and the distortion of these orbits by the gravitational forces of the Sun, the Moon, the pressure of the solar radiation and friction with the upper strata of the atmosphere. Work is also in progress on the delineation of the Earth's shape and on a system of ground measuring instruments.

In 1975 scientists installed in Borowiec a laser-measuring apparatus developed jointly by Czechoslovakia, GDR, and Poland. The device helps establish the position of artificial satellites, exact to 1.2 metres.

Professor S. Grzedzielski heads the research into the solar wind. In recent years he and his collaborators have tackled the influence of non-stationary solar phenomena on the solar wind. They found that the mutual influence of the solar wind and the interstellar matter depends on the solar activity and is subject to oscillations reflecting the 11-year cycle of changes in that activity.

In space meteorology Poland obtains data from meteorological probes and Soviet-launched "Meteor" satellites. These studies concentrate on the circulations in the atmosphere and their relationship to solar activity, which has a vital bearing on the weather.

Poland also conducts teledetection (Earth resources) experiments applying to the natural environment and industrial influence upon it.

The work concerning outer space communications is largely of a utility character. It centres on the use of the "Intersputnik" space communications network, embracing the socialist countries, which was established in November, 1971. Poland has a ground communications station in Psary, near Kielce, which is used to relay television programmes and also will be used for telephone communications in the future.

Bioastronautics

Bioastronautics is another domain of intensive and valuable experiments – carried out both in ground laboratories and in man-launched space objects, notably satellites. (eg, Kosmos 782 and 936). These experiments concern the influence of the changing gravitational forces on living organisms, the influence of weightlessness, biological rhythms, the influence of ion radiation, etc. Polish scientists have discovered, for example that microscopic changes occur in living cells under the influence of weightlessness. If a space flight takes less than three weeks, the changes are negligible and disappear following readaptation to gravity.

Bioastronautics experiments are closely related to aviation medicine. They help explore the range of human capabilities in space flights, applying both to human physiology and psychology. Space psychology today is a weighty and lively realm of bioastronautics. Accordingly, the Polish candidates for cos-

Scientists and technicians of several countries assist the installation and checkout of the satellite Intercosmos 19 on the launch vehicle in the preparation building.

All photos: Novosti Press Agency

Weather research is another fruitful area of cooperation for Polish scientists. Here a Soviet meteorological rocket is prepared for launching from the Soviet research ship *Akademik Korolyov*.

Novosti Press Agency

The climax of Soviet-Polish collaboration came in 1978 when a Polish cosmonaut flew to the Salyut 6 space station aboard the spacecraft Soyuz 30. Commander of the spacecraft was Col. Pyotr Illyich Klimuk of the USSR; alongside was cosmonaut-researcher Miroslaw Germaszewski, a Major in the Polish army (right).

Novosti Press Agency

monauts have undergone a preliminarily selection procedure and training at the Military Institute of Aviation Medicine in Warsaw. The first space flight by a Pole involved a number of original Polish experiments, some of which were carried out independently and others in cooperation with the USSR. They largely concerned bioastronautics. The Polish space flight can be regarded as a prelude to Poland's increasingly extensive participation in the space research programmes to be carried out in Earth orbit.

Acknowledgements
We thank the Polish Embassy in London for their cooperation in obtaining this article.

MILESTONES/*Continued from page 189*]

sance satellites which supply high-resolution images of surface targets by ejecting film capsules, KH-11 obtains its high-resolution imagery by digital transmission. A similar satellite was launched 14 June 1978.

12 NASA issues a request for proposals for the adminstration of a Shuttle Student Involvement Project. The project will be a nationwide competition within the United States, to begin September 1980, for the opportunity to submit proposals for scientific and engineering experiments to be flown on the Space Shuttle in late 1981 or 1982. A similar programme to involve US college-level students is in preparation.

13. Third and final test firing of Space Shuttle Solid Rocket Booster is successfully completed at Thiokol Corporation's test site near Brigham City, Utah. Burn duration was just under 120 sec; peak-level thrust approximately 1,390,000 kgf; specific impulse 265 (vacuum). Thiokol achieved a planned 2 per cent increase in burn rate by adding iron oxide to the propellant mix (which slightly shortens thrust duration). This is designed to increase the Shuttle's payload delivered to polar orbit by 1,500–1,600 lb (680–725 kg). Present aim is to lift payloads of 14,500 kg into polar orbit from Vandenberg AFB.

13 NASA announces plans to retain an expendable launch vehicle capability at the Eastern Space and Missile Center, Florida, as a backup to the Space Shuttle during the transition to full Space Transportation System operations. Use will be made of the standard 3910 version of the Delta launch vehicle, which can place satellites of up to 2,400 lb (1, 100 kg) into geostationary transfer orbit. Commercial users of these Deltas will be charged $22 million per launch in the early phases of the transition period.

13 NASA defers Orbital Cloud Physics Experiment scheduled to fly as a Spacelab payload aboard the Space Shuttle in 1982 because "technical problems in the transition from ground laboratory to a space flight environment have resulted in increased cost and schedule risks . . ." Instead, the specially-built equipment will be used in ground-based laboratories in the agency's weather and climate research programmes. It is hoped to fly a cloud physics experiment on a future Spacelab mission.

15–16 NASA launches seven sounding rockets – two Nike Black Brants, two Astrobee Ds and three Super Arcas – from San Marco platform offshore of Kenya to study total eclipse of Sun. Primary objective: to study changes in the electrical structure of the Earth's middle atmosphere and the temperature distribution in the solar corona.

SRC REVIEWS ITS BUDGET

We have previously had cause to comment on the dwindling resources for scientific space research in the United Kingdom. The struggle to maintain effort in this and other areas of fundamental research receives strong emphasis in the 14th Annual Report of the Science Research Council. The effects are being felt in the lack of career opportunities for young scientists in universities and polytechnics and in the development of new science.

The SRC Report reviews the substantial progress in engineering fields to which the Council attaches high priority – Marine Technology, Polymer Engineering and the Teaching Company – and the initiatives it has taken in support of microcomputer technology, software and robotics. It emphasises the importance it attaches to the Council-wide scheme of grants for collaborative research programmes with industry. For example, over £1M of proposals have already been received from a wide range of industries and first grants made in the Co-operative Research Scheme launched during the year and new education and training schemes (the Collaborative Training Award Scheme and the Ex-part-time Scheme) were introduced.

The Council has been concerned that the high rate of technological development means that the scientific knowledge of many graduates in industry is out of date. A pilot programme of post-experience training for those experienced in industry but needing to be updated in technological advances is likely to involve the Open University in co-operation with other academic institutions. As a forerunner to a scheme for new graduates, the Council is going to support a limited number of bursaries at some polytechnics.

Progress on the new central facilities, in particular the Nuclear Structure Facility, the Synchrotron Radiation Source, the Spallation Neutron Source and the High Power Laser equipment is charted, the Council recognising how essential access to advanced research facilities is if UK scientists are to stay in the forefront of their fields.

A special article marking the Science Board's first 10 years shows the increasing part which the large capital facilities are playing in the Board's programme. Neutron beams, sychrotron radiation and laser beams assist the physicist, the chemist and the biologist.

The UK Infra-Red Telescope on Mauna Kea in Hawaii was inaugurated by HRH the Duke of Gloucester on 10 October 1979. Agreement was reached with the Spanish authorities for the installation of the Northern Hemisphere Observatory on La Palma.

In a specially contributed article Professor R. L. F. Boyd, CBE, FRS, reviews the activities which fall within the compass of the Astronomy, Space and Radio Board. The quality of the research results being derived from these programmes – in terms of cost-effectiveness – speak for themselves:

The Board's responsibility

"The Board supports front line research in universities aimed to provide the most penetrating insights into phenomena throughout the Cosmos. For these purposes the Board often needs to provide national or international facilities in the UK or overseas in collaboration with European or other partners including the European Space Agency (ESA). The near boundary to the Board's concern is the bottom of the earth's atmosphere. Astronomy is an observational science which is concerned with exploring the universe and with applying the laws of physical science (or even refining them as with gravitation theory) in the light of data acquired by observations of celestial phenomena throughout the electromagnetic spectrum. These studies are augmented by information from cosmic ray and meteoritic particles and by a search for gravititional waves, and are supported by mathematical physics. The space responsibility has two aspects. First, since electromagnetic waves over most of the spectrum cannot penetrate our atmosphere, spacecraft and balloons are essential to modern astronomy. Second, the solar system which constitutes the immediate environment of the earth is increasingly accessible to direct experiments. The term 'radio' in connection with the Board refers particularly to the fact that active experimentation in the environment of our planet may be carried out by using radio waves as probes. The physics and technology of radio communication are the responsibility of the Engineering Board."

Scientific and technological appeal

"The excitement of the cosmic sciences continues to attract very able students, to the benefit of university departments and, through them, the country. But there are perhaps two other attractions. The motive for insight into the physical universe, unabated by the centuries, is matched today by the creative challenge of a subject which depends ultimately on advance at the frontiers of technology. Alongside this must be set the vision of young people whose formative years have seen space science give birth to a space technology which bears increasingly on daily life and which, they are convinced, has an even greater significance for the future."

Success and its requirements

"In spite of the decrease in its budgets, which have been declining steeply for the last four years, the Board can report again this year substantial scientific successes in each of its main fields. Unless the budget is improved, however, the space segment will become ineffective by the mid-eighties and the resulting loss of coherence in the Board's policy will jeopardise the future work."

Radio astronomy

"Radio telescopes are the main tools for the study of free electrons in celestial systems and, together with infra-red instruments, for the study of molecules in space. The SRC has from its inception followed the recommendations of the Fleck Committee and supported no university radio astronomy observatories beyond those of Cambridge and Manchester. It has however provided facilities for a wider university community with the Appleton Laboratory's telescope at Chilbolton. This dish, planned originally for radio communications experiments, operates in the 10-35 GHz range. It is being used most successfully in studies of extragalactic objects especially in a transatlantic collaboration as one station of a very long base-line interferometer. Molecular line emission and electron motions in supernova remnants are among the galactic phenomena studied.

"The Mullard Radio Astronomy Observatory at Cambridge provides with its five telescopes very effective tools to explore the physics of both galactic and extragalactic sources at high angular resolution. The Nuffield Radio Astronomy Laboratory at Jodrell Bank is continuing to employ its Mark IA and Mark II telescopes with success, while at the same time making major progress on setting up its Multitelescope Radio-Linked Interferometer. The complete system involves the erection of three new dishes automatically controlled from Jodrell Bank and having radio links satisfying stringent phase stability requirements.

"In the millimetre range useful work can be done in daylight hours with instruments mounted on reflectors designed for infra-red and visual observations. The Anglo-Australian Telescope and the Infra-Red flux collector at Tenerife are being

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* *Report of the Science Research Council for 1978-79 published for SRC by HMSO. Price £5.25 net.*

used in this way and the United Kingdom Infra-Red Telescope on Hawaii will soon be available, but the Board recognizes the need for a dedicated specially-designed millimetre-wave telescope and has continued studies based on the Appleton and Rutherford Laboratories for a 15 m dish precise enough to operate down to the atmospheric window at 0.8 mm and to even shorter wavelengths. This telescope would be used for, among other things, the study of emissions from interstellar matter, for example from the regions of star formation."

X-ray astronomy

"X-ray astronomy is the prime diagnostic technique for matter at temperatures of millions of degrees and thus for studying some of the most energetic power sources of the universe. The instruments on the Copernicus and Ariel 5 satellites continue to provide data for a stream of important papers often in collaboration with groups making correlated ultraviolet, optical, infra-red and radio observations. Ariel 5 is expected to re-enter the atmosphere soon. Ariel 6 (which was launched from Wallops Island, USA, on 2 June 1979) carries two small X-ray observing systems on a spacecraft whose primary payload is concerned with heavy cosmic rays. This is the last satellite planned in the successful Ariel series. The ESA's EXOSAT X-ray satellite is due to be launched in 1981 for the accurate measurement of the position of X-ray sources. To provide for future developments in X-ray astronomy the SRC is financing the development of the National Physical Laboratory's techniques for figuring X-ray mirror systems. A lapping and polishing machine which has been installed as part of the Laboratory's programme is to be supplemented by a grinding and turning facility to be provided by the SRC. These machines are being used in the first instance to prepare mirrors for flight by UK/US teams on US Aries rockets, partly as prototypes for more ambitious satellite payloads.

"Two recent successful flights of a 38 centimetre diameter MIT/Leicester University telescope on NASA sounding rockets have yielded 2-dimensional images from three supernova remnants. An X-ray contour map at 0.15-1.12 keV superimposed upon a Palomar Sky Survey optical photograph of the Cygnus Loop shows reasonable accord with the symmetrical blast wave model."

Gamma-ray astronomy

"Hard X-rays and gamma-rays, which may arise from elementary particle interactions, penetrate the atmosphere to a sufficient depth to enable their observation by balloon-borne instruments. The Board has a balloon programme in various disciplines of about 10 flights a year and provides centrally through the Appleton Laboratory a number of facilities. Good use is made of these facilities in the hard X and gamma-ray spectral regions."

Cosmic ray studies

"Cosmic rays constitute the only matter reaching us from beyond the Solar System. The Board's main facility for cosmic ray studies is the array at Haverah Park operated by the universities of Durham, Leeds and Nottingham. This continues to provide very effectively for studies of primaries up to more than 10^{19} eV energy and for investigating their mass spectrum. Use is also made of balloon payloads. A heavy primary detector has been built and installed as the main payload of Ariel 6 and it is hoped other satellite opportunities will arise."

Ultraviolet astronomy

"Results from the International Ultraviolet Explorer satellite, a cooperative project between the SRC, NASA and ESA, are rapidly transforming the subject. This satellite, launched early in 1978, operates over the wavelength range from the atmospheric cut-off down to 1150 Å in which most atoms emit their resonance radiation. As a diagnostic tool for many stellar, interstellar and galactic objects it is unique. As an observatory for guest programmes one-sixth of the time is dedicated to the UK and many UK scientists are obtaining excellent results. Ultraviolet astronomers no longer have available the superb stabilised Skylark rocket, because of recent financial cuts, but are able to make use of balloons in a narrow range of the near ultraviolet. It was for such work that the SRC's Stabilised Balloon Platform had its two highly successful flights this year. Future flights of this platform will be used for observations in other parts of the electromagnetic spectrum."

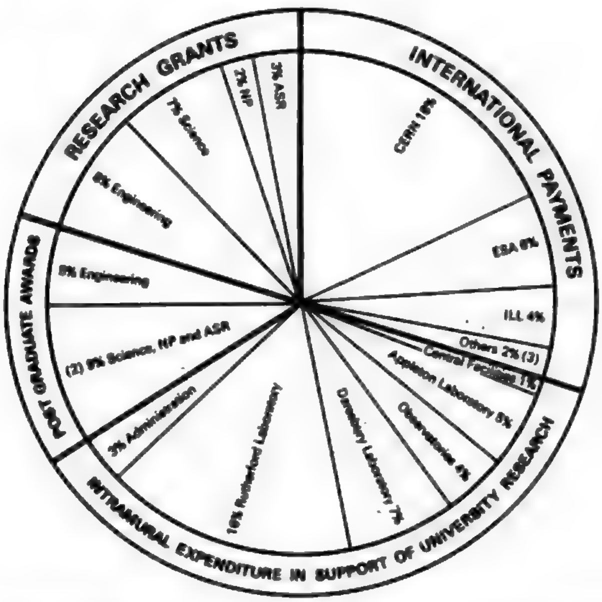
Astronomy at visible wavelengths

"Conventional astronomy, employing the most advanced photon detection systems, both operates at the frontiers of knowledge and provides the spectroscopic, astrometric and statistical framework on which all the other astronomies depend. The frequency range of group-based instruments (sometimes called the optical region, though optics are used over most of the electromagnetic spectrum) is well served by several very good observatories including the unsurpassed Anglo-Australian Telescope at Siding Spring, Australia, and the nearby UK Schmidt Telescope (operated by the Royal Observatory, Edinburgh). The availability of these instruments and their facilities to UK universities is enabling our country to regain something of its prestige of earlier centuries in ground-based astronomy. Supporting these in the Southern hemisphere are the smaller instruments of the South African Astronomical Observatory which UK workers use effectively. The Northern sky, however, remains a severe problem as telescopes in the UK are at a climatic disadvantage and the only other instrument to which UK workers have access at present is a relatively small telescope in Egypt. Meanwhile negotiations with Spain for a site in La Palma on which to erect three telescopes were concluded on 26 May 1979. The Isaac Newton Telescope (INT) will be moved there from Herstmonceux and plans are well advanced for a 4.2 m telescope as the SRC's prime northern hemisphere facility. Completion is expected in the mid-eighties under the management of the Royal Greenwich Observatory (RGO). By that time NASA's 2.4 m Space Telescope should be in orbit, attended from time to time by Shuttle astronauts and certainly heavily oversubscribed with observing programmes of which 15% (by time) is guaranteed to Europe, in return for the provision by ESA of one of the instruments for the telescope."

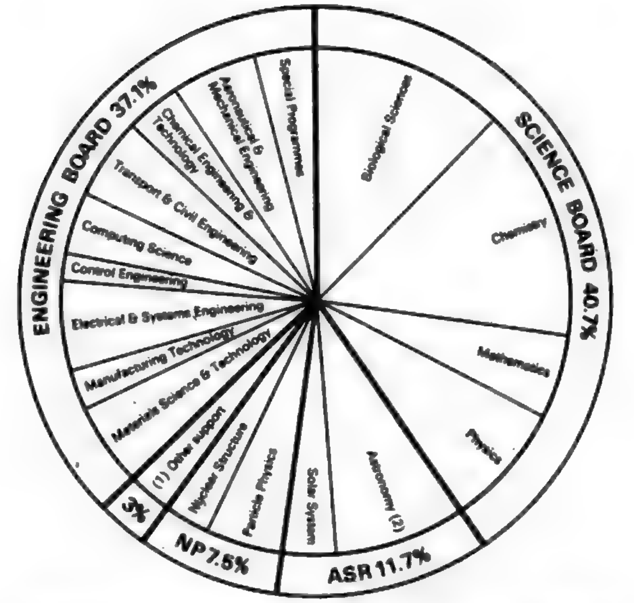
"During the final phases of its operation at Herstmonceux, the INT has been used to discover a velocity structure which is unique at present in extragalactic studies. The investigation concerned the filaments of M82, once thought the most spectacular evidence of explosions in galactic nuclei, but of late having been interpreted in terms of light scattering in a galactic halo. The RGO spectrograph in combination with the INT was used to obtain high dispersion spectra in the filaments of M82 and the structure seen in the emission lines was such as to point convincingly to the violent expulsion of material. The structure was similar to that seen in the Crab Nebula and one which is difficult to explain by models depending on scattering but having a natural explanation in the explosion hypothesis."

Infra-red astronomy

"Infra-red radiation makes possible observations of very cool systems and penetrates dust clouds which totally obscure in the visible. The study of the birth processes of stars and the detection of molecules are major roles. A significant part of the infra-red spectral range can be observed from high altitude terrestrial observatories, while the use of balloons in the SRC's programme provides further facilities and extends the range. For some years the Board has supported a facility at Tenerife operated for the community by Imperial College. This 1.5 m flux collector (so called because for reasons of economy its optical precision is not high) will continue in operation at least for the immediate future. The United Kingdom Infra-red Telescope (UKIRT) in Hawaii was expected to become fully

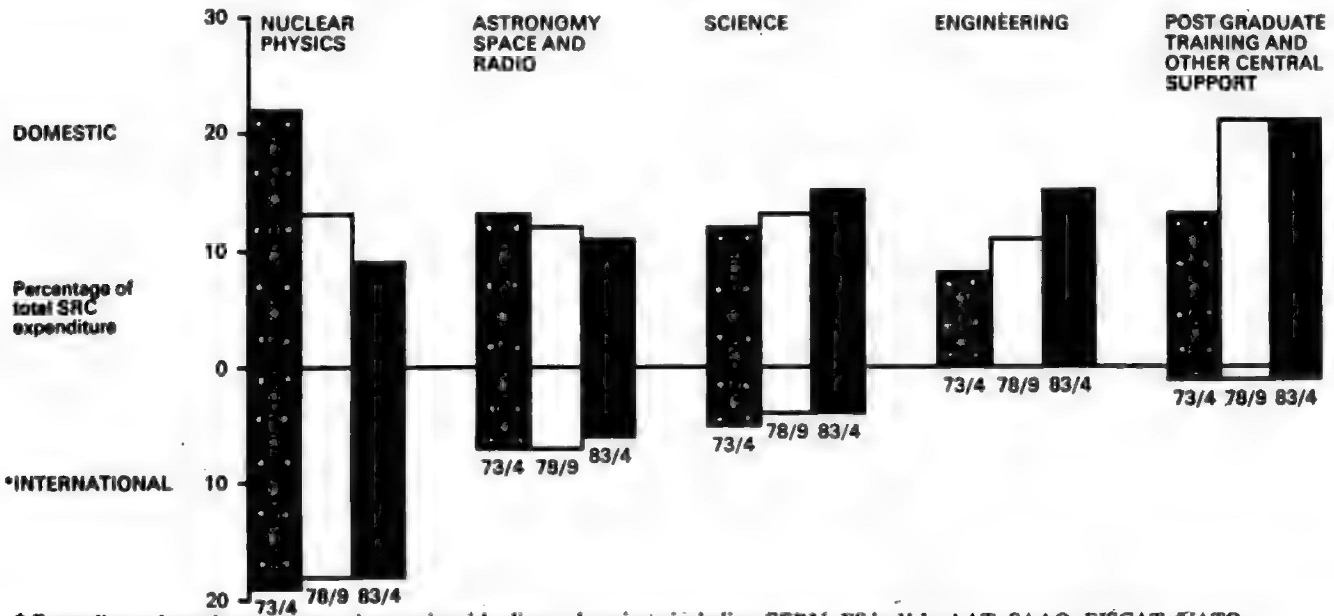


Expenditure by sectors (1) 1978–79. Key: (1) Expressed as a percentage of the total SRC expenditure in 1978–1979. (2) Expenditure on postgraduate awards for Nuclear Physics and Astronomy, Space and Radio was less than 1 per cent. (3) Others include—NATO, Anglo-Australian Telescope, South African Astronomical Observatory, Institute des Hautes Études Scientifiques, European Science Foundation, European Incoherent Scatter Facility.



Direct expenditure to Universities and Polytechnics (through research grants and postgraduate awards) by Board and Committee 1978–79. Key: (1) Expenditure by Energy Proposals, Joint SRC/SSRC, Cooperative Research Grants and Science-based Archaeology Committees. (2) Expenditure by Astronomy I and Astronomy II Committees.

DISTRIBUTION OF ACTUAL SRC DOMESTIC AND INTERNATIONAL EXPENDITURE BY BOARDS, ETC FOR 1973/74, 1978/79 AND PROPOSED EXPENDITURE FOR 1983/84



* Expenditure through payments to international bodies and projects including CERN, ESA, ILL, AAT, SAAO, EISCAT, NATO.

NOTE:

The figures for postgraduate training and central support for 1978/79 and 1983/84 include a transfer of funds to the Council of about 3% of the Council's budget to cover higher postgraduate fees from 1977. Also included for 1978/79 and 1983/84 are funds for operating the Council's central computers which in 1972/73 were provided by the Science and Nuclear Physics Boards.

operational during 1979. This 3.8 m instrument is already showing evidence of justifying the economic 'thin mirror' technique incorporated into the design by the ROE team and image resolution better than 2 arc sec is anticipated."

Solar physics
"The Sun's upper atmosphere and its variable effects on the Earth's environment are not well understood. The key lies in the ultraviolet and X-ray observations of increasing sensitivity and resolving power. A substantial amount of work in solar observations and related laboratory and theoretical astrophysics is carried out in individual universities and in the Council's Establishments. Additionally, the Appleton Laboratory, Birmingham University and the Mullard Space Science Laboratory were all involved with overseas groups in a major contribution to NASA's Solar Maximum Mission to be launched at the end of 1979. The third spacecraft in the NASA-ESA International Sun-Earth Explorer triad was launched successfully in November 1978 and carries one UK experiment. Two experiments from Imperial College are to be carried on the NASA-ESA International Solar Polar Mission, for launch in 1983."

Ionospheric/magnetospheric studies
"ESA's GEOS 2 satellite was launched into a geostationary orbit in May 1978 and data from this spacecraft and GEOS 1 are being analyzed by several UK groups. Both satellites carry an experiment from a UK group. Following the successful high latitude campaigns using Skylark and Fulmar rockets small rockets of the Petrel type continue to be used in high latitude campaigns to study auroral phenomena, and for atmospheric studies at South Uist. High latitude ionospheric phenomena will shortly be accessible to UK scientists through the special European incoherent scatter radar project EISCAT to which the SRC is partner with five other countries; the construction of this facility is proceeding well.

"A group at Sussex University have continued their general investigation of space plasmas and electrostatic wave propagation in the ionosphere and magnetosphere. They have shown that localized electron "wells" within the magnetosphere are generated in the plasma sheet by large amplitude ion cyclotron waves which evolve from a turbulent ion wave cascade driven by earthward travelling protons. A particular highlight of the group's analysis of GEOS data is the identification of $n+\frac{1}{2}$ electron gyrofrequency harmonics."

Planetary and geophysical studies
"Exploration of the moon and of our near planetary neighbours in the solar system carried out by NASA spacecraft during the last decade is providing new and exciting information about the origin, evolution and structure of planets and their atmospheres. Individual scientists from UK universities have been involved in the teams planning these missions, in the study of data from them and in the analysis of lunar samples. Oxford University, as partners in a joint experiment for the Pioneer Venus Orbiter launched in May 1978, have contributed the first British scientific instrument to leave the Earth's immediate gravitational environment.

"Together with their collaborators, Oxford University have for nine years used facilities won on US satellites for observations of the Earth's atmosphere which have enabled studies to be made for the first time of the global behaviour of planetary waves, the largest features to be seen in the atmosphere's circulation. To contribute to studies of the outer atmosphere in addition to geodetic research a laser ranging facility is to be built at the RGO to enable very accurate determination of satellite orbits."

Data handling and theoretical studies
"Individual universities depend heavily on the use of the Council's central computing facilities for theoretical studies and for handling data from spacecraft. Photographically recorded data from the Board's observatories is available to the community and is analyzed on a number of central plate analysis facilities. The Board hopes to establish soon several central image processing centres to handle astronomical data interactively. This will also provide for handling data from the NASA-ESA Space Telescope."

Possible future vehicles for space studies
"In the past UK scientists have had a balanced space programme involving flights both on ESA and NASA spacecraft and on a series of satellites (Ariel) and large sounding rockets under the SRC's direct control. With the end of the Skylark rocket programme and of the Ariel series, the Board is seeking a way ahead, recognizing that satellites built for and dedicated to a single objective are beyond its means. Taking account of the varied interests of UK scientific groups, it has concluded that, if possible, individual satellite flights should satisfy a range of disciplines and that the basic system must be re-usable either in design or, preferably, in terms of hardware. This suggests the use of a system compatible with NASA's space shuttle. Even then it is questionable whether the Council could afford the development costs of a project unless they can be shared. As a move in this direction the Board has undertaken at the invitation of NASA joint studies of a Multidiscipline Refurbishable Satellite. These studies show a distinct economy is attainable in this way and it is hoped that detailed design studies may lead to an agreed collaborative programme for the eighties. Other possibilities are also being studied."

HERMANN OBERTH

85 Years: A Life for Space Flight

By Ernst J. Sellner*

Introduction
Professor Hermann Oberth celebrated his 85th birthday on 25 June, 1979. His biography is defined by his endeavour to reach unknown and unexperienced distances by means of scientific findings and human knowledge. With these ideas the previously unknown teacher of physics and mathematics investigated contemporary concepts, while living among the former ethnic group of the "Siebenbürgen" people in the seclusion of Transylvania, now Rumania, where he was often derided and ridiculed as an outsider. However, many people before him dreamed of flying into space and have described or planned the dream, and deserve a mention here:

- *as scholars and philosophers of their time:* Ptolemy, Copernicus, Kepler, Newton, and others,
- *as visionaries and writers:* Jules Verne, Lasswitz, Ley, Dominick, and others;
- *as enthusiasts, pioneers, and advocates of a new epoch:* Ganswindt, Tsiolkovsky, Goddard, Hohmann, Sänger, Wernher von Braun, and others.

More than half a century ago, Hermann Oberth pointed the way to space and revealed the technically simple and clearly realistic principles which were prerequisites of space flight: in 1923 he published *Die Rakete zu den Planetenräumen* ("The Rocket into Interplanetary Space"). This thin booklet of a mere 87-pages, contained the foundations and the perspectives of the development and implementation of conditions, requirements and elements for an advance into outer space.

Wege zur Raumschiffahrt ("Ways to Space Travel"), published in 1929/1930 expanded the theses of the previous book. In the course of the following technical developments theorists, scientists, and space flight experts dealt with the problems which had been made evident by Professor Oberth. Some aspects of his work even raised the interest of politicians of that time. Oberth, though, always tried to evade the attention of those "other categories", as he called them. He wanted only to pursue in peace his theses and ideas on the possibility of reaching the space outside the Earth's atmosphere by means of the calculable and real machine – the rocket.

Today, after the remarkable successes of the last decade, the 85-year-old pioneer works more intensively on the essence of his ideas than ever. For him, nowadays, genuine progress seems to be subject to logical extensions and conceptual limits. Oberth, therefore, introduces psychoanalysis in order to conquer the cosmic dimensions by parapsychological elements, just as space flight was previously made feasible by classical mathematical and physical equations.

His creative genius does not allow Hermann Oberth any rest. During the pursuit of his hobbies, gardening and walking, he forms ideas for posterity and shapes his legacy for the future.

Genius of Space Flight Technique
At the dawn of the history of space flight three names dominate: TSIOLKOVSKY – GODDARD – OBERTH

As early as 1903 the Russian **Konstantin Eduardovich Tsiolkovsky** (17th September, 1857 – 19th September, 1935) depicted in basic treatises the scientific relationships between flight and exhaust velocities and take-off, fuel, and burn-out masses. His "basic rocket equation" and numerous other findings grant him a place of honour in the history of space flight as one of the founders of Astronautics.

The American **Robert Hutchings Goddard** (5th October, 1882 – 10th August, 1945) was the first American scientist to deal with rocket development. From 1915 onwards he carried out experiments which were based on rocket principles applied to liquid propellant propulsion. Robert Goddard is considered one of the founders of space flight.

Hermann Julius Oberth, a German born in Hermannstadt (Siebenbürgen/Transylvania) on 25th June, 1894, became the father of modern space flight by his early and fundamental essays on rocket and space flight techniques. His predictions, made as early as 1923, have come true and constitute the basis for continuing developments.

These theses, so courageously calculated in those days, are today accepted as valid:

1. *With rockets one can leave the Earth's atmosphere and stay outside for a length of time.*
2. *With rockets the force of gravitation can be overcome and the Earth can be left behind.*
3. *Man himself can also leave the Earth without risk and travel through space.*
4. *Manufacture and use of rockets can be economically useful.*

Without a doubt hardly any other scientist can look back on the vital use of his ideas with such satisfaction. Today Oberth is therefore considered the mentor and genius of space flight.

Professor Hermann Oberth who celebrates his 86th birthday on 25 June. We take this opportunity of sending him our warmest greetings.

**F.B.I.S.; Vice-president of the "Hermann-Oberth-Gesellschaft" and The "Internat.Förderkreis für Raumfahrt Hermann Oberth/Wernher von Braun."*

Wernher von Braun (3rd March, 1912 – 16th June, 1977) was the indefatigable representative and leading architect of the overwhelming achievement of our century which finally allowed people to travel to and from the Moon. He succeeded, like no other before him, in translating ideas of such gigantic dimension into technical reality. He helped space flight to become part of our present life and he helped mankind to find the way to the remote parts of our Solar System. Wernher von Braun's death left a deep gap in our generation.

In his determination and foresight Hermann Oberth carries his ideas from their origin onwards into the unlimited reaches of the Cosmos as a great living symbol of earthbound mankind.

HERMANN OBERTH

A Chronicle of a Modest Life

June 25th, 1894	Hermann Oberth is born in Hermannstadt (Siebenbürgen, now Rumania), the son of Dr. Julius Oberth and Valerie, born Krasser (daughter of the poet Friedrich Krasser).
1896	His family moves to Schaessburg (Siebenbürgen).
1906	The pupil is fascinated by Jules Verne's "Journey to the Moon".
1907/1908	The Grammar school pupil searches for the clue to trips to the Moon and hits on the idea of employing rockets.
1909	First essay on a "Spaceship".
1912	Final examination (Abitur) at Schaessburg Grammar school.
1913/1914	Medical studies at the Technische Hochschule in Munich (including basic studies of aerodynamics under Professor Emden).
1914	Formulation of the basic equation for propulsion.
1918	Marriage with Mathilde, born Hummel.
1919/1921	Oberth continues his studies in Munich, Göttingen and Heidelberg. His interest is focused on rockets which he designs and with which he experiments.
1923	His first book *The Rocket into Interplanetary Space* is published.
1924	Oberth becomes Professor for Physics and Mathematics in Schaessburg. First contact with Tsiolkovsky.
1928	
1928	Oberth is engaged for the construction of a rocket for the film "Frau in Mond" (The Lady on the Moon). He is injured by an explosion during the manufacture of the rocket.
1929	*Wege zur Raumschiffahrt* ("Ways to Space Travel") published as his second book.
1930	Invention of the "cone jet". First liquid-propellant rocket motor tested in Berlin-Ploetzensee is a success for Oberth.
1931	Co-founder of the rocket test ground in Berlin-Reinickendorf.
1932/1933	Oberth turns down offers to go to Russia and Japan.
1937	Oberth attracts attention in Germany.
1938	Oberth offered a chair at the Technische Hochschule (Technical University) in Vienna.
1940	He moves to Dresden/Germany.
1941	Employment in Peenemünde (construction of the so-called "A-weapons").
Oct. 3rd, 1942	The first modern long-distance rocket of the world is successfully tested at Peenemünde, the A-4.
1943	Works on a solid-fuel rocket in Reinsdorf.
1944	Due to war-time bombing the ammonia-saltpetre production in the LEUNA factories ceased, bringing Oberth's work to an end.
1945	Oberth is reunited with his family in Feucht near Nuremberg.
1948/1952	Offers to work in Switzerland and Italy.
1953	Retired as a scholar. Return to Feucht.
1955	Called to Huntsville, Alabama, U.S.A. Work on Moon rockets and rocket development.
1958	Returns to Germany. From this time on Oberth received acknowledgements, praise and honours from all over the world.
Sept. 19th, 1963	The "Deutsche Raketengesellschaft" adopts the name of "Hermann-Oberth-Gesellleschaft" (Hermann-Oberth-Society).
June 25th, 1969	In honour of his 75th birthday the "Internationaler Foerderkreis Hermann Oberth" is founded in Salzburg/Austria. The name of Hermann Oberth thus shall be carried and documented throughout the world. Shortly afterwards Hermann Oberth witnesses the launch of Apollo 11 in the United States, the first Moon landing enterprise in the history of mankind.

Hermann Oberth spent the following ten years of his well-earned retirement in the seclusion of Feucht as "Honorary Freeman" of this town. But his creative urge to find new answers and definitions is still insatiable.

MINDSTRETCHERS!

As a further step in our quest for more imaginative writing on Astronautical themes, we are inviting authors to submit short essays of 1,500 to 2,500 words for early publication. We are particularly seeking new ideas, crisply and imaginatively expressed, with the accent on the Future.

We hope this new feature will serve as a viewpoint/ideas airing service, catalysing thoughts and providing grounds for other short contributions expressing contrasting viewpoints.

Some possible subjects areas: ● Philosophy of space explorations; ● alternative forms of propulsion; ● advanced technological use of Solar System resources; ● detection of planets of other stars; ● conditions and environment for life and intelligence; ● Cyborg techniques (artificial intelligence, bionic human structures); ● problems of communication with extra-terrestrial intelligence, e.g. coding and de-coding of "languages" for SETI.

Hopefully, the essays will throw up ideas which can be expanded into major articles for *Spaceflight* and *JBIS*.

THE HERMANN OBERTH MUSEUM

By Dr. Erna Roth-Oberth*

Introduction

The Hermann Oberth Museum was established in an old Patrician manor house belonging to Professor Oberth in Feucht near Nuremberg on 25 July, 1971. It is maintained by the Hermann Oberth Museum Society. Professor Oberth's son-in-law, Mr. Josef Roth, arranged it and now looks after it.

All the world echoes the triumphs which have been achieved by mankind in the conquest of space during the last 35 years. The history of astronautics began, according to Willy Ley who was a science author and observer of its development, in Berlin in 1929. The Verein für Raumschiffahrt [VfR] (Society for Space Travel) had been moved there from Breslau (Silesia) during the year. Ley wrote:

"Rocket theory and experimentation in the Society advanced rapidly. Our work was based on the theoretical work of Oberth and his ideas were given practical form. Unfortunately, both Goddard in America and Tsiolkovsky in Russia did not get any kind of similar practical support.

"As a result, America and Russia did not seriously consider large-sized rockets until World War II. And both countries based their subsequent developments not on the work of either Goddard or Tsiolkovsky, but on the Oberth-inspired V-2. This fact unquestionably, if ironically, eliminates Goddard and Tsiolkovsky from competition and makes Oberth the true 'father of the space age'. As an eyewitness to this particular chapter of history, I can present the final proof of this genealogy of our present day rockets – both American and Russian". (Excerpt from Space World 1969, Vol. 1, No. 8: "How it all began").

Von Braun's Tribute

Wernher von Braun wrote about the importance of the theoretical work of Professor Oberth for space flight:

"In these days of organised technical progress we are used to regard scientific and technological developments as the natural result of vast budgets and the highly interconnected work of large staffs of specialists. Of course, it is absolutely true that projects as large as the utilization of nuclear energy or the exploitation of space cannot be achieved without money and an army of scientists, engineers, technicians, and skilled workers. Hermann Oberth's book The Rocket into Interplanetary Space, *however, should let us recall the old truth that great scientific discoveries and inventions can neither be financed nor organised, but must be born with all the pains of labour in the brains of creative individuals. This book is the work of such an imaginative individual, who ventures into unexplored territory, independent of his contemporaries' opinions and attitudes."* (Excerpt from Wernher von Braun's foreword for the republication of *The Rocket into Interplanetary Space*, 24 June, 1929).

Pioneering Achievements

The founders of the Hermann Oberth Museum Society are of the opinion that the great American and Russian space flight museums do not make sufficient allowance for this idea of the secluded "inventor". As one cannot hear the quiet gurgling of the well in the middle of a roaring river, so the development of space technology, which has grown to gigantic size in recent years, makes us forget that is started with a few formulae – and Hermann Oberth's firm belief in the correctness of his ideas.

The Hermann Oberth Museum Society has therefore taken on the task of increasing the appreciation of the pioneering achievements of Hermann Oberth, as well as providing proof of his importance in paving the way for the development of space flight. He was the first to reach for the slide rule when the idea of real space flight arose; and he produced the first rocket design which was based on actual calculations. His ideas and calculations, expressed in numerous letters, theses, essays and designs provided the proof that space flight was technically possible. With prophetic clarity, Oberth described almost all essential elements of today's large-sized rockets as well as the tasks which have been partly resolved and are partly still waiting for realisation; these have often been mistakingly taken for inventions of recent years by some contemporary writers.

*Daughter of Prof. Hermann Oberth.

Professor Oberth and his daughter Dr. Erna Roth-Oberth at the entrance to the Museum.

Oberth Exhibits

Among others the following exhibits are on display in the museum:

- Model of Oberth's cone jet.
- Model of test stand No. 7 from Pennemünde, on which the big rockets were assembled from pre-fabricated parts, as well as the test stand from which the first A-4 was launched; the first real flight took place on 3 October, 1942.
- A control gyro for an A-4 rocket which does not differ in essentials from any modern gyro.
- Model of a lunar vehicle designed by Oberth.
- Model of a Saturn 5 rocket together with an Apollo command module and launch escape system.

Above, a corner of the Hermann Oberth Museum with examples of technical contributions to rocketry and astronautics dating from the 1920s.

Left, the old Patrician Manor House in Feucht near Nuremberg which houses the "Hermann Oberth Museum".

- Model of the Space Shuttle and various competing designs which never entered production.
- Model of the interior arrangement of the Space Shuttle.
- Model of a space station, whereby two rockets, rotating around each other, created a centrifugal force which is equal to the gravitational force on Earth, and which house the recreation rooms for the astronauts.
- Model of a space mirror to illuminate the dark side of the Earth, which also can be used for supplying energy to cause climatic changes and to keep seaways open by the melting of icebergs.
- Drawing of a catapult to bring material from the Moon into an orbit around the moon where it should be collected by electrical spaceships and brought to the assembly hall of the space station.

Above, Oberth in the section of the Museum devoted to Astronomy and Physics.

Right, in this photograph taken in April 1979 Oberth poses before the drawing of the Modell B rocket designed to explore the upper atmosphere. At upper right, the cover of *Die Rakete zu den Planetenräumen* (The Rocket Into Planetary Space) and the Modell E rocket.

- Drawing of the "speed multiplicator".
- All books written by Hermann Oberth.
- Copies of letters and newspaper articles, in which Oberth replies to objections to space flight and gives proof of the chances of space flight.
- A compilation of formulae which assisted Oberth in the finding of important facts for the construction of large-sized rockets and for manned space flight in general.
- Numerous display boards with pictures and descriptions of historical stages of astronomy and astronautics.
- The most important decorations and acknowledgements for Hermann Oberth.

The museum is open on weekdays between 8 a.m. and 4 p.m. and by appointment on Saturdays and Sundays.

SKYLAB DEBRIS

The National Aeronautics and Space Administration has prepared 'personalized plaques' for 20 Australian citizens who cooperated in providing the agency with debris they had gathered from the Skylab space station. Skylab returned to Earth over the Indian Ocean and Western Australia on 11 July 1979. A fragment of the Skylab material provided by the individual is attached to each plaque.

Soon after Skylab fell, causing no damage or injury, NASA dispatched a small group to Australia to interview eye-witnesses and otherwise determine the facts of the reentry, including ascertaining the pattern of dispersion of the falling pieces.

A secondary objective was to bring back small samples for laboratory analysis to determine the effects six years of space exposure had had on certain materials. Citizens who voluntarily surrendered pieces of the debris were assured they would be returned.

The plaques express the appreciation of NASA for the assistance rendered by the finders. They are signed by Dr. William R. Lucas, director of NASA's Marshall Space Flight Center, Huntsville, Alabama, where the material was analyzed and the plaques were made.

Of the 22 specimens brought to Marshall by the centre employees who returned from Australia in late July, 20 were determined to be from the Skylab.

Analysis of the debris showed that all materials performed well, attesting to the soundness of the space station design. In some cases they performed well beyond expectations.

Laboratory study also indicated that Skylab did not experience re-entry heating quite as high as had been predicted. The space station's re-entry disintegration began at an altitude about 19 km (10 miles) lower than had been expected, resulting in a 'footprint' or area of debris distribution much smaller than anticipated; about 74 km (40 miles) wide and 4,400 km (2,400 miles) long, compared to the expected 185 by 7,400 km (100 by 4,000 miles.

Residents of thinly-populated Western Australia continue to find and report pieces of the spacecraft. In late October, the State Emergency Services Group at Esperance sent photographs and descriptions of five small pieces that had been found. Earlier, a Perth writer who was on a Skylab "safari" found a large piece of aluminium weighing 80 kg (180 lb) near Balladonia. It has been determined that the aluminium most likely is a door from the film vault in the Skylab workshop.

Another significant "find" after the American group left Australia was a pair of titanium spheres which held nitrogen. They were found near Rawlinna, in the area where two large oxygen tanks were found earlier.

Although no hardware finds have been reported farther north (downrange) than Rawlinna, NASA authorities reason that several pieces are yet to be found within a few hundred kilometres of Rawlinna, the footprint ending at 26 deg. south and 131 deg. east, about 926 km (500 miles) northeast of Rawlinna.

Heavier Skylab elements not yet found include the orbital workshop film vault, and portions of the solar observatory, including the structure, control moment gyros and Experiment SO54.

JAPANESE ASTRONAUT

Japan expects to make a series of man-monitored space experiments during the next 15 years, according to Mr. A. Kubozono of the National Space Development Agency's Office of Space Shuttle Utilization. A Japanese national will conduct the First Materials Processing Test (FMPT) aboard Spacelab which is tentatively planned for Japanese Fiscal Year 1984 (early 1985), writes Gerald L. Borrowman.

The National Space Development Agency of Japan is currently studying the equipment needed for the space experiments and calling for proposals from national institutes, universities and others.

SKYLAB PLAQUES. Dr. W. R. Lucas (right), director of the Marshall Space Flight Center, and James E. Kingsbury, director of Science and engineering at MSFC, examine plaques containing small samples of Skylab debris. The plaques have been mailed to 20 Australians to mark NASA's appreciation of their assistance in recovering the materials.

NASA

The current concept for the FMPT involves the use of a long Spacelab shared with other users. It will contain Japanese life sciences research equipment. Material sciences research equipment such as materials experiments and organic/inorganic experiments will be mounted on a pallet. The FMPT is scheduled for launch in February of 1985 with one Japanese payload specialist. The activities of the Japanese on-board experiments will be monitored and controlled from facilities at Tsukula Space Center in Japan.

The Japanese will have a four-step payload specialist selection procedure. In the first step the emphasis will be on professional and scientific qualifications; the remaining three steps will be primarily medical and physical evaluations. Four payload specialists will be selected even though only one will fly on the first Japanese Shuttle/Spacelab flight. The remainder will serve as ground backup crewmen for the first flight and will be available to fly on future Japanese missions.

SATELLITES DOWN-UNDER

Australia is to have her own satellite for relaying television, telephone and data services across the length and breadth of the country. "For many Australians, satellite communications offer the only practicable solution to the problems of how to provide any services at all within a reasonable time scale," said Mr. A. A. Staley, Australia's minister for Post and Telecommunications.

There will be no question of buying systems outright from America. It is important that Australian industry has a major role in the development, Mr. Staley said. The Australian Government will not sign any agreement for the supply of such systems that does not provide safeguards for Australian participation.

CHASING A SOLAR ECLIPSE

A challenge faced the Canadian Research Council's Space Research Facilities Branch in preparing for the total eclipse of the sun which was visible in central Canada in February of 1979. For the past two decades the Space Research Facility Branch had been responsible for all scientific rocket and balloon launches in Canada, writes Gerald L. Borrowman. The team had provided the launch and recovery operations for Canadian and American experimenters performing research in the upper atmosphere. When the US space agency determined there was no suitable site for launches to investigate the eclipse in the US, they turned to the Space Research Facility Branch for assistance. All that was known at the time was the path of total eclipse across Canada and the time when the shadow passed.

Finding a suitable site along the path was not an easy task. Rocket launch sites are largely determined by logistics. They must be remote enough to avoid conjested urban centres, yet accessible to roads or other transportation means to facilitate the movement of personnel and equipment. For the 1979 eclipse, these criteria were met by the Northern Ontario community of Red Lake.

Red Lake may not be a congested urban complex, but more than 5,000 people live and work in the five communities of the site. They are miners, housewives, trappers, bush miners, schoolchildren, and lumbermen and all were concerned with the effects of a rocket launch programme on their lives. To allay anxieties, SRFB staff spent many months touring the area and explaining the programme, its limited hazards, and its benefits to the people and to science. The enthusiastic response of the local population during the exercise is no small tribute to this effort. Bush pilots went so far as to enact a self-imposed radio silence for the duration of the launches in order not to interfere with the telemetry signals.

"Remote launch sites are not new to SRFB," says Jack Tarzwell, Head of Operations. "A permanent rocket range exists at Churchill, Manitoba, for a continuing programme of studies of the *aurora borealis*. Changes in the research programme coupled with the rising costs of the launches has led the Branch over the past few years to "expeditionary" sites. These more flexible arrangements began in 1966 with launches at Resolute Bay, NWT, and were followed by the two launches to observe eclipses at East Quoddy, Nova Scotia, in 1970 and 1972. The following year the new techniques were put to a real test with launches into the magnetosphere from Cape Perry, NWT."

Almost 2,000 km north of Edmonton, Cape Perry was the launch site for two Black Brant rockets carrying 18 experiments into the upper atmosphere during the long Arctic night. The launchings paved the way for the extensive operations that took place at Red Lake. Winter conditions proved helpful in the Red Lake operation since tourists and prospectors and mosquitoes flood the region during the summer.

The Red Lake launch in terms of numbers alone was a significant exercise for the rocket team. When the researchers had drawn up their final plans for the event, 35 rockets were scheduled to be sent aloft over a seven-day period. This meant much more than simply "touching a match to the fuse." Some vehicles were timed to match satellites passing overhead, while Canada's Black Brant VA was to fly during the period of totality, holding a position to allow instruments to view the Sun during the eclipse. "It is one thing to launch a rocket to a specified altitude and keep it within the impact area, as we did at Churchill and the other sites," says Terzwell, "but it is something else to put a window in that rocket, send it more than 100 km into the atmosphere and say, 'look at the Sun and don't turn your head!' That was the problem we faced."

For the Black Brant flight, "tossing the stone" with the required accuracy was partly solved by the installation of a guidance system recently developed in Sweden. A sounding rocket's flight path is partially determined by the launching ramp, and placing a guidance system in the rocket booster has the effect of extending the ramp length from a few metres to several kilometres. With this system, both flight accuracy and the predicted point of impact are improved. Its efficiency was demonstrated by the operations team after the launch; the recovery team was directed to the impact point of the Black Brant booster to within a few metres. Recovery of the rocket body was hampered only by the fact that the point of impact was the centre of a river bed.

The Black Brant was one of many types of vehicle launched at Red Lake. Instead of a neat, uniform group of rockets, the international team prepared and fired a range of models and sizes from the 2 metres long Astrobees and Lokis to the 9- and 10-metres long Nike Orion and Tomahawks. Each has its own characteristics and idiosyncracies, and the launching mechanisms and methods were as unique as the rockets. When this variety is combined with the many kinds of delicate experiments carried aloft, some idea of the potential problems become evident. Despite this, the process went smoothly and no serious hitches developed. With continuing advances in rocket technology, the NRC launch team expects to be even better prepared when the next total eclipse in Canada occurs.

RADAR MAPPING OF VENUS

Studies which could lead to the development of an unmanned NASA spacecraft to make topographical radar maps of Venus in the mid-1980s are being conducted by Martin Marietta Aerospace, Denver Division, and the Space and Communications Group, Hughes Aircraft Company, under contract to the Jet Propulsion Laboratory in Pasadena.

When the $500,000 study contracts are completed this summer, one of the two companies may be chosen to develop

the Venus Orbiting Imaging Radar spacecraft, if the mission is approved by Congress.

Planned for a Space Shuttle launching and five-month trip to Venus, the spacecraft would first be placed in a 300 by 19,000 km (185 by 11,800 miles) Venerian orbit for a two-month gravity study of the planet. The craft's orbit would then be circularized at 300 km (185 miles) for a 120-day radar mapping sequence, which would cover nearly all the surface of Venus at low resolution 1.0 km (0.6 mile) and about 2.5 per cent at high resolution, 100 metres, or 328 ft.

The primary mapping instrument aboard the spacecraft will be a side-looking synthetic aperture radar similar to one flown in 1978 aboard NASA's experimental oceanographic satellite, Seasat.

SUN-EARTH INVESTIGATIONS

Nasa is asking scientists to propose experiments for a programme of coordinated satellite measurements designed to provide a better understanding of the near-Earth space environment and Sun-Earth relationships. The programme, called Origins of Plasmas in the Earth's Neighbourhood, would attempt for the first time to examine the collective behaviour of specific components which make up the geospace system – the near-Earth interplanetary medium, magnetosphere, ionosphere and upper atmosphere.

An understanding of this system is a prerequisite to understanding Sun-Earth relationships and their effect on our planet's environment, including short- and long-term weather and climate prediction and the impact of solar phenomena on communications. Current understanding, gained from previous satellite programmes, clearly shows a high degree of interaction between all geospace components.

The programme calls for simultaneous observations from a minimum of four spacecraft, placed in specific key regions of space and operating in widely different orbits.

Basically, the aim is to investigate the flow of mass, momentum and energy through the solar wind and electrified environment near Earth, using instrumentation for remote sensing and closeup measurements of electromagnetic radiation, fields, particles and plasmas.

The satellites, launched by the Space Shuttle over a one-year period in the mid-1980s, would be placed to observe each of the major geospace plasma source regions (solar wind, ionosphere) and storage regions (ring current, plasma sheet, distant geomagnetic tail).

Each spacecraft would have significant orbit-change capability to provide observational flexibility and permit exploration of a vast volume of geospace. The spacecraft would operate for at least four years.

Although the programme has not been authorized by Congress, scientists were asked to submit their proposals by 15 March 1980, in order to ensure maximum scientific participation in the programme and design of the spacecraft.

Objectives of the proposed mission are to:

- Understand the physical process controlling the origins, entry, transport, storage, acceleration and loss of electrified matter, and electrical current in the Earth's neighbourhood.
- Understand cause-and-effect relationships among the closely coupled solar wind, magnetosphere (the magnetic envelope that surrounds Earth) and the ionosphere (the electrified part of the atmosphere).
- Trace the flow of matter and energy through the geospace system from their interplanetary or atmospheric origins to ultimate deposition into the atmosphere or loss to the interplanetary medium.
- Assess the importance to Earth's environment of variations in energy deposition into the atmosphere caused by plasma processes.
- Utilize the unique capabilities of the programme for solar wind and other studies.

This will be the first programme to address the geospace environment as a whole. Past observations have been obtained primarily by single-point satellite measurements, and more recently by multi-point measurements designed to study the linkage between no more than two geospace components.

NASA REVISES SPACE TRACKING

NASA will change its space tracking and data acquisition activities when the Space Shuttle and the Tracking and Data Relay Satellite System become operational in the 1980s. The decision results from a study of responsibilities at the Goddard Space Flight Center for tracking and data systems activities. The changes are intended to insure that tracking stations and network operations will be managed most efficiently and effectively using both government and contractor personnel and resources.

The Tracking and Data Relay Satellite System in 1982 will take over all of the tracking and data acquisition support of low Earth-orbiting spacecraft. At that time, the Spaceflight Tracking and Data Network NASA's worldwide network of tracking stations, will be closed, with the following exceptions:

- The Alaska station will be retained until Landsat 3 becomes inoperative, anticipated in 1984.
- The Goddard station will be retained until the International Ultraviolet Explorer spacecraft becomes inoperative, anticipated in the mid-1980s.
- The Merritt Island, Florida, and Bermuda stations will be converted to launch support and range safety facilities.
- The Goldstone, California, Australian and Spanish stations will be retained for support of geosynchronous and highly elliptical orbit spacecraft.

The Rosman station in North Carolina expects to cease operations in January 1981. This facility had been supporting the Applications Technology Satellite 6, which is no longer operating, and the Orbiting Astronomical Observatory, which will complete its mission in November 1980. The Rosman station is operated for NASA by the Bendix Field Engineering Corporation, which employs about 120 people at the site.

The stations to be closed in 1982 include Hawaii; Guam; Quito, Ecuador; and Santiago, Chile. The station in Winkfield, England, will be closed in 1980.

The Spaceflight Tracking and Data Network capabilities of the Goldstone, Australian and Spanish stations are similar to those required for the Deep Space Network stations at the same locations. Combining the capabilities at each station will achieve more efficient use of the facilities, and save money. The facilities at Goldstone, Australia and Spain will be consolidated into a network under the management of NASA's Jet Propulsion Laboratory in 1983–1985.

SPACE EYE ON FROST

Throughout most of the United States, drops in night-time temperatures only signal a need for warmer clothing the next day. In Florida's multi-million dollar agricultural belts, the stakes are higher. Many of the foods and other products people take for granted, such as citrus fruits, salad greens, ornamental

plants and more can be ruined by the icy fingers of a night-time freeze.

Forecasting when and for how long, and also exactly where and when frost will occur, is vital for Florida's biggest industry. Failure to turn on wind machines, fire up citrus grove heaters or take other measures can mean the loss of an entire crop.

On the other hand, the costs of standing by to perform these functions runs up to $43,000 per hour for the citrus industry alone, and the expense of using all protective means can hit $6 million for each night of operation. Guessing either way just isn't good enough.

Where do the growers get their answers? For the past several years the answers have come from space, and the system is being improved.

Entering the payoff stage is a project by the National Weather Service, the University of Florida and NASA's John F. Kennedy Space Center to develop a computerized forecast ability for freeze conditions.

In use as the eyes of the system is the National Oceanic and Atmospheric Administration's (NOAA) weather satellite with a formal name of Geostationary Orbiting Environmental Satellite 1, which is in a stationary orbit 35,880 km (22,300 miles) over the equator in a position above Colombia, South America.

The satellite provides forecasters with both regular photographs and infrared pictures every 30 minutes. Two aspects of the photos allow the weathermen to predict night-time freezes in Florida.

First, the infrared pictures from the satellite reveal heat levels instead of visible features. Second, freezing conditions rarely occur during cloudy conditions in Florida, so the satellite sees ground or treetops temperatures rather than those of cloud tops on most nights.

The readings of temperatures from the satellite are accurate to within two degrees Fahrenheit and each tiny element or "pixel," of the transmitted picture covers an area about 8 km (5 miles) on a side.

The satellite beams its information to a receiving station at the National Environmental Satellite Service in Suitland, Maryland. It is then fed in a digital format to computer complexes in field stations throughout the country.

The station of interest to Florida agriculture is NOAA's National Weather Service installation at Ruskin. NASA's contribution to the system, besides that of originally launching the satellite, is a highly sophisticated computer and image analyzer which transforms the digital data from electrical signals to a multi-colour display of temperature profiles.

Each colour in the television map represents a specific temperature range, giving forecasters an accurate picture of the advancing cold air. The satellite data, plus reports from field locations, allow forecasters to present a much more accurate and detailed summary of what is occurring across the state.

To predict what will continue to occur over as much as eight hours, the computer uses a University of Florida developed programme or "mathematical model" to predict temperature profiles in specific locations through the long night.

Using historical data from the 10 key stations, plus other factors such as soil type, humidity, wind and other variables, the computer updates the forecast. The update covers the eight hours following the forecast, and is revised every two hours through the night.

"When fully developed, we'll see the whole state rather than just selected areas," said an enthusiastic Fred Crosby, meteorologist-in-charge of the weather office at Ruskin. "This is going to be a powerful tool for us. It's very impressive for us to see this kind of thing compared to spot temperatures.

"In time, it will significantly refine the science of predicting Florida temperatures – or those for any other area where this technology is made available."

The new tool allows fruit growers to make the tough decisions on freezing conditions. Crop losses are minimized and the unnecessary use of fuels is eliminated. But agriculturists outside Florida can also benefit from the system.

Temperature sensitive crops in many other states could use the satellite and computer combination to develop their own models of local temperature change, protecting their crops. Apples, peaches, cranberries and a variety of other truck crops in states from Maine to California could be saved by advance temperature knowledge.

UV SATELLITE REPORTS

The International Ultraviolet Explorer satellite, launched in 1978, has provided scientists from 17 countries with more than 9,000 images of astronomical objects that could not be obtained by ground-based instruments. Nearly 200 scientists have used these images in support of about 250 research programmes and more than 100 scientific papers have been written about the results of these observations. The satellite is helping to answer the most basic questions in astronomy – what stars, nebulae and galaxies are and how they develop.

A cooperative effort between NASA, the United Kingdom and the 11-nation European Space Agency, the ultraviolet satellite programme is managed by NASA's Goodard Space Flight Center, Greenbelt, Maryland for NASA's Office of Space Science.

The satellite, launched on 26 January 1978, has more than accomplished its announced objectives. The primary goals were to obtain high-resolution ultraviolet observations of astronomically bright stars, planets, stellar and planetary atmospheres, and to gather lower resolution observations of fainter, more distant objects such as quasars, Seyfert galaxies, pulsars, X-ray sources and other cosmic phenomenon.

Secondary objectives for the satellite include providing experience in the combined use of satellite and ground-based observations. The satellite is also evaluating techniques for accommodating the many observers expected to use the space telescope, now scheduled for launch aboard the Space Shuttle in 1983.

The satellite is in a geosynchronous orbit – that is, it stays nearly stationary over a point on the equator. This enables astronomers to interact with the satellite much as they would with a ground-based telescope.

NASA established observation facilities for scientists from other nations at the Goddard Center and a similar facility was established by the European Space Agency near Madrid, Spain. These facilities allow astronomers with very little background in spacecraft operations to use the satellite without undergoing tedious specialized training courses.

The satellite is equipped with a reflecting telescope, a spectrograph and a television camera detector for relaying the spectral data in video form and was designed by Goddard.

International agreements give NASA 16 hours of observation time daily and the European Space Agency and the United Kingdom have 8 hours to share. The time allotments are based on each participant's contribution to the mission. Each part of the electromagnetic spectrum tells scientists something important and different about the life cycle of an astronomical object. The wavelengths of the spectrum being examined by the satellite lie between 1150 Angstroms and 3200 Angstroms – short wavelengths that do not penetrate our atmosphere. The hotter an object, including celestial objects, the shorter the wavelengths emitted.

Scientists get only a narrow glimpse of emitted spectra when confined to making observations from below the atmosphere, but the satellite opens a window to the little-studied but important ultraviolet region of the spectrum.

Scientists have already made a wealth of discoveries with the satellite's data, discoveries that will shed more light on the type of stars in our galaxy, the material between the stars, the

myriad of radio wave and X-ray emitting sources, and on nearby galaxies and far-away quasars.

By looking at the gas and dust of the interstellar medium, scientists hope to determine the composition of the "grains" floating in space between the stars and thus learn more about how our own star, the Sun, was born.

Through investigation of stars in our galaxy, still more may be learned about our star, the Sun. The satellite will look at hot stars and the outer atmospheres of cool stars that are similar to the Sun. These cool stars are relatively cool at their surfaces but have extremely rarefied outer atmospheres, or coronas, with temperatures of about 500,000 degrees Celsius (1 million degrees Fahrenheit). Above the obscuring layer of Earth's atmosphere, the satellite will be able to determine these stars' temperatures, density and chemical composition. These findings will complement and extend observations made by NASA's Orbiting Astronomical Observatories and the European Space Agency's TD-1 satellite.

The only limitations to the satellite's lifetime are the amount of propellant available to the stablizing system and the life of the batteries which power the satellite twice a year when it enters the Earth's shadow. If the present rate of propellant usage continues, the satellite could last for 30 years.

SATELLITE FOR LUXEMBOURG?

British Aerospace Dynamics Group at Stevenage are conducting a funded study for Radio Tele Luxembourg (RTL) aimed at defining a television broadcast satellite system for the Grand Duchy, writes K. J. Rooney. The geostationary satellite would transmit high power signals in the 11.7 GHz–12.5 GHZ broadcast band for reception by small receivers over a large part of Western Europe. These small receivers could be mounted on domestic rooftops, and consist of an antenna dish about 80 cm in diameter, and an FM/AM translator. The resultant signal can be displayed on a normal TV set. Alternatively, larger community receivers could be employed, with subsequent TV redistribution via cable.

The satellite is designed as a derivative of the ECS (European Communications Satellite) for which BAeDG are Prime Contractors. Including the Maritime and French domestic versions, eleven models of this satellite class are already on the order books.

The RTL study is competitive, with Hughes Aircraft Company and the Eurosatellite Consortium undertaking similar funded contracts.

SOLAR SYSTEM FORMATION

Could the Earth have formed in the middle of a giant protoplanet something like Jupiter? Is the Solar System, with its relatively small, rocky planets close to the Sun and large gaseous planets farther away from the Sun, typical of planetary systems around other stars?

Many scientists think the answers to both questions may be yes. Recent computer simulations strengthen this view, and include a major role for giant protoplanets.

For discovery of planets around other stars, and for charting the history of the Solar System, the finding of answers to these questions is essential.

A team of scientists at NASA's Ames Research Center, Mountain View, California, has shown that giant protoplanets would have been orbitally stable in the early Solar System. They also have developed a formula for determining sizes and positions of planets in planetary systems in general. They are now looking for likely arrangements of planets around other stars. These results were presented on 5 December 1979 at the American Geophysical Union Meeting, San Francisco.

One of the most frequent explanations of solar system formation is that at some time very early in the Solar System's history a number of giant gaseous protoplanets revolved around the young and growing Sun. These giant protoplanets may have had the same mass as Jupiter, but were larger in size and hence more diffuse. The Ames researchers suggest that the rocky material in these giant protoplanets rapidly (in a few thousand years) fell to the centre of the protoplanets, forming rocky cores. The mass of such a core would be comparable to the mass of the Earth.

The Pioneer Jupiter and Saturn spacecraft have produced evidence for the existence today of such rocky cores in the giant gas planets Jupiter and Saturn.

As the Sun grew to its present mass by in-fall of material from the solar gas cloud, its gravitational field would have become stronger. Eventually, it would be strong enough to strip away the atmospheres of the giant protoplanets, leaving behind only their rocky cores. These remnant cores, it is argued, are the terrestrial planets.

If the Earth, Mars, and Venus are in fact remnant rocky cores of giant gaseous protoplanets like Jupiter, their protoplanets would have had to be stable for at least a thousand years.

The NASA-Ames team has shown that two Jupiter-mass protoplanets orbiting the Sun in the present-day orbits of Earth and Venus would, in fact, be stable for several thousand years. If the masses of the protoplanets were increased substantially (four times Jupiter's mass), then the one in Venus' orbit would have been ejected from the Solar System in a few decades.

For these findings the team used a computer code designed to calculate accurately the orbital motions of a model planetary system. They also found that much more massive protoplanets (Jupiters in size) could have existed in stable orbits in the region of the outer gas giants, Uranus and Neptune.

A dramatic finding was that the orbits became unstable very suddenly. This meant catastrophic ejection of a planet from the Solar System, with the body suddenly sailing off on a tangent trajectory. Earlier, Dr. P. E. Nacozy, University of Texas, had shown that an instability catastrophe might exist. Therefore, the team looked for a simple way to tell whether a particular type of planetary system would be orbitally stable.

They ran numerical experiments in a large computer, a CDC 7600, to model several types of possible planetary systems. Surprisingly, they found that stability of planetary systems depends mainly on the *ratio* of orbit sizes (the ratio of their distances from the large parent body, the Sun). Stability is not affected by how close or how distant individual planets are from each other.

The Ames team now is attempting to develop a set of mass and orbit-ratio categories to describe planetary systems revolving around other stars than the Sun. No other planetary systems have yet been found, but sophisticated new methods of search are in planning stages.

Calculations like those by the NASA-Ames team will help scientists to locate planetary systems around other stars, and to determine whether such systems occur frequently, or whether the Solar System is a rare phenomenon.

SPACE AID FOR YACHTS

All yachts in this year's Royal Western/Observer Single-handed Transatlantic Race will carry special transmitter equipment to send an automatic signal via satellite. The signals will be processed and the organisers will know the exact location of every yacht throughout the race.

The transmitters work through Argos, a world-wide environmental data collection system. Argos is a space programme

developed by the United States and France involving NASA, the National Oceanic and Atmospheric Administration (NOAA), and the French Centre National d'Etudes Spatiales (CNES).

The Argos system locates transmitters linked to the system at any point on the Earth's surface and collects the data they transmit. The Tiros-N satellite was launched in October 1978 in a circular polar orbit at an altitude of between 521 and 546 miles, and it takes 101 minutes to revolve around the Earth.

The satellite "sees" all the transmitters located within a circle of 3,140 miles diameter as it goes on its orbit from north to south pole on each revolution of the Earth. Its instruments receive all the messages from the yacht transmitters within sight and fix the time of the reception. The data is decoded, stored in a magnetic recorder on board the satellite and then transmitted to one of the three telemetering stations on the Earth – at Gilmore Creek and Wallops Island in the United States and Lannion in France.

All the data is transmitted then to the CNES centre in Toulouse for further processing and position computation and onward transmission to the race information stations – at The Royal Western Yacht Club in Plymouth, *The Observer* press centre in London and the race end receiving station at Newport, Rhode Island.

The design of the Argos system is such that each transmitting yacht needs only to have a simple transmitter weighing no more than 6 kg., with an energy consumption of approximately 300 mW. All yachts transmit on the same frequency of 401.650 MHz and at regular intervals – every 40 to 60 seconds – with a message that lasts less than one second indicating atmospheric (or barometric) pressure and air temperature for scientific purposes as well as giving exact location.

USSR SPACE STATION PLANS

A recent interview by the deputy Director of the Soviet Space Research Institute has thrown new light on Russian space plans for the 1980s. The interview was reported in the periodical *Soviet Weekly* [1], writes Brian Harvey.

Professor Georgi Narimanov outlined the three main objectives of the Soviet piloted programme:

- Developing reusable transport and ferry systems
- Finding the correct balance of cosmonauts and automation in operating orbital stations
- Setting up space stations with crews of 20 to 30 cosmonauts orbiting for 2 to 3 years.

Experience gained with Progress and Soyuz spacecraft would help with the design of reusable Shuttle craft which would have two stages, both recoverable. However the most unusual aspect of the interview was when the Professor stated that "to obtain maximum lift capacity for the first stage it will probably use an air-breathing engine."

Large stations, which will follow the advanced Salyut, will be made up of modules which can be docked with a central service area. Such modules will be standardised and of either cylindrical or spherical form.

A number of inferences can be drawn from this interview. First it gives us a good idea as to the size of space station the USSR is working towards. Such a station would require a Shuttle carrying a load of 8 to 10 crew members to make operations economically viable.

Second, it confirms the approach of linking different modules and units together to build up such a station, highlighting the need for a space tug, of which Cosmos 929 was almost certainly the precursor [2].

Third, whilst it confirms that the USSR is very much involved in Shuttle development, the interview confuses the issue further as to the true nature of the Soviet Shuttle. Two years ago there was some speculation that the Russians might use air-breathing hypersonic flyback aircraft [3]. If this is the case, it shows them moving on a very different track from the Americans, one which Western research in the 1960s appeared to regard as unpromising.

The timing of the introduction of the Soviet Shuttle is still unclear. This interview, because of its lack of precision, indicates this will be later rather than sooner. In the last analysis, indications of an imminent Shuttle test may depend on US observations of pad activity at Tyuratam, and on the traditional last-minute breakdown of press secrecy that surrounds any major new Soviet space enterprise.

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"MAN AND SPACE" ART COMPETITION

The "Young Europeans and Spacelab" programme, which has been developed by the European Space Agency, is intended to popularize space activities and, in particular the Spacelab programme and its evolution, to promote scientific and technical hobbies among young people and to encourage European cooperation. In this context, several events are planned, some of which will offer young Europeans the possibility of carrying out experiments on Spacelab.

In the framework of this programme and with the aim of illustrating its objectives, an Art Competition is being organized by the European Space Agency on the theme: **MAN AND SPACE.**

All young Europeans from Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom, who are between the ages of 12 and 21 years in 1980 are invited to illustrate the theme, choosing their own form of expression such as drawings, paintings, sculptures, models, posters, poems, short stories, plays, audio-visual presentations and musical compositions, etc. The competition will be organized at two levels, national and European.

The national authorities sponsoring the competition will be responsible for its local organization, will define the procedures for participation, will establish selection criteria, carry out the selection and award the prizes foreseen at national level.

The European Space Agency will organize an exhibition of the works selected at national level and will present the prizes foreseen at European level.

The exhibition will be held at – and with the co-sponsorship of – the "Conservatoire National des Arts et Métiers", in Paris.

The closing date for submission of works to the national selection boards is June 1980.

The closing date for presentation to ESA of the selected works is 15 September 1980. The exhibition will be held during November/December 1980.

The authors or team leaders of 5 works per country will be invited by ESA for a four-day visit to Paris, on the occasion of the opening of the exhibition where their works will be exposed.

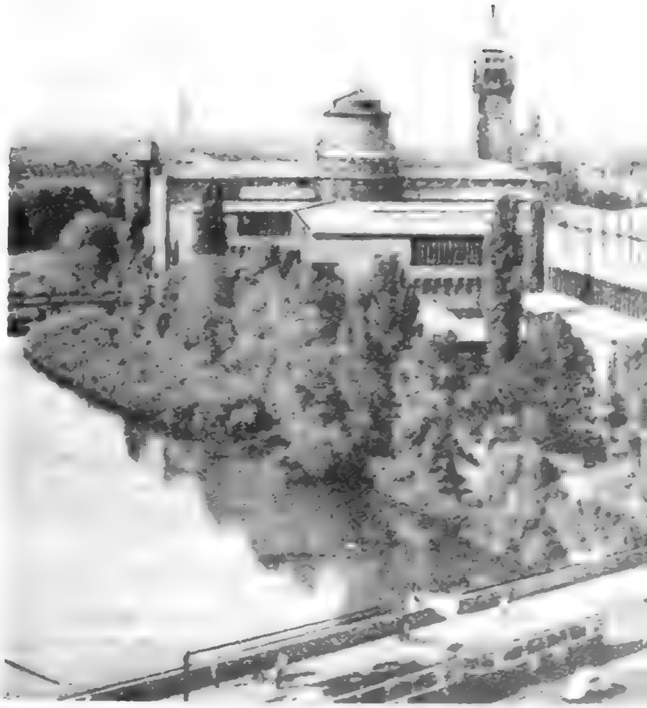
30TH CONGRESS OF THE INTERNATIONAL ASTRONAUTICAL FEDERATION

The 30th Congress of the International Astronautical Federation was held in Munich (FRG) from 16 to 22 September 1979, under the chairmanship of Mr. Roy Gibson, Director General of ESA.

More than a thousand participants from some thirty countries met for the purpose of listening to numerous lectures (several hundred, pread over some fifty sessions), and in order to meet their colleagues from all parts of the world. As usual, the International Academy of Astronautics and the International Institute of Space Law joined in the activities of the Congress, which was devcted to the theme of "Space developments for the future of humanity".

Three symposia centred on this theme took place. The first, devoted to satellite applications, included Earth and Oceans observation programmes as well as communication satellite programmes. The second dealt with space transportation systems, while the third was devoted to manned space operations. In addition to these three symposia there were meetings covering all aspects of astronautics, including the issues of economics and space spin-off, international law, safety, space utilization (solar energy), not forgetting less prosaic subjects such as exploration of the Solar System and even the question of communication with intelligent beings from outer space.

Among the speeches made at the formal opening ceremony, mention should be made of those by the Prime Minister of the State of Bavaria and the Secretary of State of the German Federal Ministry of Research and Technology. Those participants that so wished also had the opportunity at the end of the day of attending lectures on various topical subjects or the showing of films. Noteworthy in this connection was the talk



Main entrance to the IAF Congress held at the Deutsches Museum, Munich, in which 30 nations participated.

Top, view of the Deutsches Museum which is located on an island in the River Isar, Munich. The IAF Congress was held in the front part of the extensive complex.

Bottom, the Congress Closing Banquet was held at Hotel "Vier Jahreszeiten" as a Buffet with dance music. In the photograph are Prof. Gerald Groves (BIS representative and IAA Trustee), Miss Helen van Gelder (IAF/IAA Executive Secretary) and Marcel Barrère (IAF Vice-President).

SPACE LAW IN MUNICH

Issues ranging from the legal aspects of solar power satellites to the organisation of space colonies were discussed at the 22nd Space Law Colloquium at Munich held as part of the 30th IAF Congress. Some 40 lawyers from countries all over the world met to continue the debates and read papers on topics which have interested the International Institute of Space Law since its founding at the 1961 IAF Congress in Washington.

The first session was devoted to energy and outer space, and space telecommunications. Several speakers dealt with solar power satellites and pointed out the need for some control over such matters as possible damage from micro-wave radiation near receiving antennae, the Polish representative, Dr. Wiewiorowska, remarking that the present treaty on liability does not cover environmental or space damage. Dr. Okolie (USA) called for the formation of a solar energy bank to which OPEC countries should subscribe. All the speakers agreed that the Bogota Declaration, in which a number of equatorial countries have claimed rights to a stationary orbit over their own countries, does not establish any rights in international law, a view already adopted by the US and Soviet governments.

An informative paper on space telecommunications was read by Professor Carl Q. Christol (USA). He stated that the International Telecommunications Union has accepted a proposal to register but not to limit orbital positions, but it has also accepted an obligation to limit overspill of broadcast material unless there has been an agreement with the country concerned. The ITU is mainly concerned with control rather than with content, and he told of a proposal to allocate bands to a nation rather than a particular satellite.

The advent of the space shuttle has revived interest in the old argument about where space begins, and this was reflected in a number of papers on the subject. While it was generally agreed that a returning shuttle should be treated as a spacecraft rather than an aircraft, particularly because of its lack of aerodynamic manoeuvrability, being described as "a flying brick", calls for a legal definition of space at various levels between 83 and 110 km were made, the Soviet delegate to the UN legal sub-committee, B. Majorski, stating that the Soviet government now favoured the establishment of a limit at about 100-110 km, or possibly less in the light of future technology. Several calls were made for the present legal regime in space to be strengthened and extended, particularly in view of the recent experiences of the return of Cosmos 954 and Skylab.

A special session was devoted to the use of nuclear power in space, and Mrs. Galloway (USA) announced that the UN is considering a new international agreement following the Cosmos 954 incident, although she asked whether the present liability treaty could be amended to include this development. While one speaker expressed reservations about the use of nuclear power sources in satellites in view of earlier US and Soviet government assurances, Dr. Perek of the United Nations said that the 1967 treaty did not prohibit nuclear power sources in space, only weapons, and Dr. Majorski confirmed that this was the view of the UN working group which has declared such uses as safe, subject to certain conditions.

Finally, the Colloquium looked ahead to the future with a lively discussion on the legal organisation of space colonies following an interesting paper on the subject by two Americans, Miss P. M. Sterns and Dr. L. I. Tennen, which argued in favour of some form of home rule or self-government with rights and obligations of citizenship for the permanent inhabitants. The Colloquium again demonstrated that the lawyers are keeping up with the advances of science, and will hopefully meet the challenges before they become live issues of dangerous controversy. The Institute will meet again this year in Tokyo as part of the 31st Congress. — CYRIL HORSFORD, M.A., FBIS.

given by Arthur C. Clarke, the well-known writer and former Chairman of the BIS, on "The Space Elevator: thought experiment or Key to the Future?".

The member societies of the Federation met twice in General Assembly. In the course of these meetings ESA was admitted as an associate member, and the possibility of an astronautical society from continental China being admitted alongside that of China-Taiwan was discussed.

In his closing address Professor Roger Lo, Co-Chairman of the International Programme Committee said: "It is hoped that the majority of the more than 1,100 participants from 32 countries received the kind of information and stimulation they expected, and that the Congress will once more have contributed to the peaceful cooperation of many nations, a cooperation which is finally devoted to the goal of providing ever more developments for the benefit and the future of mankind."

The next Congress will be held in Tokyo, Japan, from 21 to 28 September 1980. It will again be chaired by Mr. Roy Gibson, who was re-elected head of the IAF for a further year. The International Programme Committee will be chaired by Mr. J. J. Dordain, of ONERA (France).

BURNER 2 – BOEING'S SMALL UPPER STAGE

By Andrew Wilson

Introduction

Solid-propellent motors and stages tend to be ignored in astronautics literature in favour of the more sophisticated liquid-fuel variety. The boosters of the Shuttle, Titan III and Delta are well known but the same cannot be said of other "solids". The Burner 2 and 2A solid-propellant upper stages have been little publicised but their work with the Thor launcher played an important part in the development of the US Air Force's Defense Meteorological Satellite Program (DMSP).

Background

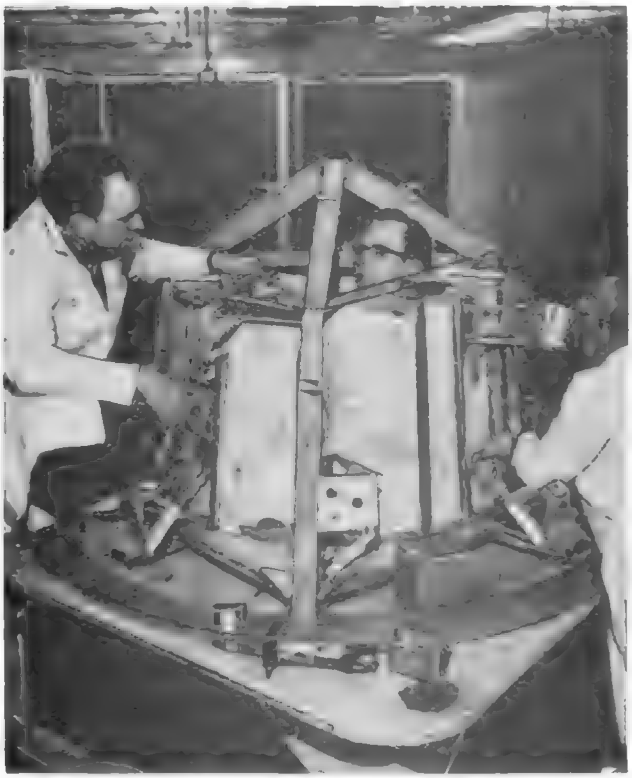
For the 1960s, the Air Force needed a low-cost guided solid-propellant upper stage which could be installed as an upper stage package on a variety of launch vehicles to inject small to medium payloads into orbit and position them accurately once there. In capability it would fall between the Scout and the more complex, costly Thor Able Star. Cost and a high reliability requirement dictated the use of a solid-propellant motor. Study contracts were awarded to Boeing and LTV on 2 September 1961 [1] by the AF Space and Missile Systems Organization (SAMSO) and on 1 April 1965 a fixed-price contract of \$6.5M for one ground test and three flight vehicles was given to Boeing.

As we will see, the capabilities designed into Burner 2 were largely dictated by the needs of the DMSP payloads and when those satellites doubled their weight in 1971 Burner 2 was modified into the two-stage Burner 2A version, with approximately twice the payload capacity.

Burner 1 was the Altair motor used extensively as Scout fourth stage and responsible for launching Block 4A DMSP satellites. It saw service between 1965 and 1966 (Table 2), after which Burner 2 took over.

Fig. 1. Representatives from the Air Force and Boeing inspect a mockup of Burner 2. Col. Goppert, chief of the Burner 2 programme, stands with hand on one of the attitude motors. Compare the size of the stage with the Burner 2A in Fig. 3. *Below*, Fig. 2, the basic conical shape and the three main beams are visible in this picture of a Burner 2 under construction. A hexagonal shape was used for the lower stage in Burner 2A (Fig. 3).

Boeing



TE-M-364-2 motor

The main motor for Burner 2 and Burner 2A's lower stage was the Thiokol TE-M-364-2, originally developed for the Surveyor programme of the mid-1960s. In its Surveyor role as main spacecraft retromotor it had to slow the vehicle down from direct approach speed to about 250 mph (402 kph) where the vernier retros could take over. Twelve seconds after burnout it was jettisoned to give clearance for Suryeyor's body on the lunar surface.

The 37 in (939.8 mm) diameter sphere was attached by three explosive bolts to Surveyor's triangular frame and with a weight of 1440 lb (655 kg) it accounted for more than 60% of the total spacecraft mass [2]. The motor carried polyhydrocarbon propellant with aluminium and ammonium perchlorate inside a high-strength steel casing insulated with asbestos and rubber. Modifications for converting the motor to Burner 2 use resulted in the propellant loading increasing to 1440 lb (655 kg) – the previous *total* motor weight – with an average thrust of 10,000 lbf (44,480 N) over a 42s burn time. The attachment structure was also modified to allow greater loads in the Burner 2 programme.

The 364 was further modified for use as an upper stage motor in other fields:

TE-M-364-2 . . . Surveyor
-364-2 . . . Burner 2 and 2A
-364-3 . . . Delta third stage
-364-4 . . . Delta & Centaur upper stage

The Centaur version yielded an average thrust of 14,800 lbf (65,830 N) and was used to send the Pioneer 10 and 11 spacecraft on their way to Jupiter in 1972 and 1973, respectively.

The motor was housed inside a conical shell which was riveted to three equally spaced vertical beams (Figs. 1 and 2) with a payload attached to the forward end. The motor employed attach points at both forward and aft ends.

Other systems

In overall dimensions, Burner 2 was 65 in (165 cm) in diameter and 68 in (173 cm) tall with a weight of 1780 lb (807 kg) at ignition and 315 lb (143 kg) after payload separation.

Guidance was provided by a three-axis preprogrammed strapped-down inertial reference system which could be programmed while the vehicle was still on the pad. The control units included timer, inverter, programmer, velocity meter, gyro unit and various electronic packages. The system took control of Thor after liftoff and directed the flight through Burner 2 separation, orientation of the vehicle with the reaction control system, Burner 2 burn and payload separation.

The accurate placement of payloads in orbit resulted from the reaction control system under control of the guidance system and was essentially the same as used by NASA's Scout Launcher [3]. Four monopropellant hydrogen peroxide 22 lbf (98 N) thrusters using two 9 lb (19.8 kg) capacity tanks gave axial acceleration and corrections in pitch and yaw for booster separation, control during Burner 2 burn and vernier correction after burnout. A cold gas nitrogen system with eight thrusters provided roll control torques during all flight phases and pitch and yaw torques during coast periods a payload orientation.

Payload shroud

The heatshield, built by Goodyear, covered both the payload and Burner stage during ascent through the denser layers of the atmosphere. The low-cost phenolic shield stood 11 ft (3.35 m) high for Burner 2 and when Burner 2A was developed a 100 in (254 cm) extension, 65 in (165 cm) in diameter, was added to the conical section, giving a total weight of 670 lb (304 kg). Ablative cork material was bonded to the conical section to provide thermal protection.

The first Burner 2 failure arose from a heatshield malfunction when, on launch 7 and during the first flight of the Atlas/Burner 2 combination, the mechanical separation system failed to function correctly and the shroud did not separate. This was the first and only time a Burner 2 failed to reach orbit, although no blame could be put on the stage itself.

DMSP

The military weather satellite DMSP system is now operational using Block 5D spacecraft built by RCA, who gained a great deal of experience in the field with Tiros. In fact, the NASA-launched Tiros-N series now in use is a version of the Block 5 satellites.

The purpose of the Burner satellites (including Burner 1) was originally classified but their orbits were revealing – Sun synchronous with 500 mi (800 km) perigees. The height was ideal for weather work of relatively high resolution and being Sun synchronous they passed over a given point on the Earth at the same time each day. They were clearly military weather satellites gathering data on a global scale to help in military planning and telling ground controllers which areas were free of cloud so that reconnaissance satellites would not waste their valuable supplies of film. Table 1 lists the different types of DMSP satellites carried by Burner 2, beginning with the 82 kg spin-stabilized Block 4A and ending with the three-axis stabilized 200 kg Block 5C. The operational Block 5D versions function at 0.5 km and 3.7 km resolution, with pointing accuracies of 0.01 deg (Block 4A achieved 1 deg.) [4]. Their full title is "Block 5D Integrated Spacecraft System" because they combine the functioning satellite with the launch vehicle upper stage. Some launch lists give their launchers as Thor Burner but the last Burner went up in 1976. In fact, the motor incorporated into Block 5D is the Thiokol TE-M-364-15 – another version of Burner 2's motor, although the two are very similar. A propellant weight of 1450 lb (657.7 kg) gives an average thrust of 9790 lbf (43.5 kN) over a period of 42.2s.

Table 1 Launch List for Burner 2 and 2A

Burner (Burner 2A) no.	Launch date	Vehicle	Payload	Launch site
1	16.09.66	TB2	Block 4A	WTR
2	8.02.67	TB2	Block 4A	WTR
3	29.06.67	TB2	Aurora & Secor 9	WTR
4	23.08.67	TB2	Block 4A	WTR
5	11.10.67	TB2	Block 4A	WTR
6	23.05.68	TB2	Block 4B	WTR
7	16.08.68	*AB2	0V5-8	WTR
8	23.10.68	TB2	Block 4B	WTR
9	23.07.69	TB2	Block 4B	WTR
10	11.02.70	TB2	Block 5A	WTR
11	3.09.70	TB2	Block 5A	WTR
12	17.02.71	TB2	Block 5A	WTR
13	8.06.71	TB2	IR test sat	WTR
14 (1)	14.10.71	TB2A	Block 5B	WTR
15 (2)	24.03.72	TB2A	Block 5B	WTR
16	2.10.72	AB2	STP 72-1 & Radcat	WTR
17 (3)	9.11.72	TB2A	Block 5B	WTR
18 (4)	17.08.73	TB2A	Block 5B	WTR
19 (5)	16.03.74	TB2A	Block 5B	WTR
20 (6)	9.08.74	TB2A	Block 5C	WTR
21 (7)	24.05.75	TB2A	Block 5C	WTR
22 (8)	19.02.76	*TB2A	Block 5C	WTR

TB2: Thor Burner 2. AB2: Atlas Burner 2. TB2A: Thor Burner 2A.
** mission failure.*

Table 2 Launch list for Thor Burner 1 (Thor Altair).

Launch date	Launch site	Initial perigee (km)
19.01.65	WTR	471
18.03.65	WTR	525
20.05.65	WTR	567
10.09.65	WTR	649
6.01.66*	WTR	—
31.03.66	WTR	634

** mission failure*

Burner 2A

The switch from Block 5A DMSP satellites to the twice as massive Block 5B versions necessitated an upgrading of the Burner 2 system. SAMSO awarded the initial production contract for Burner 2A to Boeing on 2 June, 1969 [1] (announced in August 1969) to produce a minimum-modification version from the basic Burner 2. Boeing achieved this by adding a TE-M-442-1 motor as a second upper stage and moving the flight proven equipment and subsystems of Burner 2, including guidance, flight control, reaction control, electrical and telemetry subsystems, up to the new stage. The telemetry subsystem was redesigned to incorporate an S-band system powered by the basic Burner 2 28-volt silver-zinc batteries.

The TE-M-442-1 motor allowed Burner 2A to perform two burns in each mission, leading to better trajectory shaping, orbital transfer and, generally, more flexible capabilities. It was possible with the Atlas/Burner 2A combination to send payloads into synchronous orbit but the capability was never required. The original 442 motor used a steel casing but structural weight was reduced in the 442-1 by employing titanium. This meant 524 lb (238 kg) out of the total 576 lb (261 kg) – about 91% – was given over to propellant. The 26.1 in (663 mm) diameter motor gave an average thrust of 8800 lbf (39,140 N) during its 18s burn.

Fig. 3. A Burner 2A under construction with the lower stage TE-M-364-2 motor still to be installed. The payload attaches to the three points at the forward end.

US Air Force

Fig. 4. A Thor Burner 2A on the pad at Vandenberg AFB. The dark Burner stages sit between the white booster and heatshield. In the background is the shed which could be rolled forward on rails when the vehicle was in a horizontal position. *Below*, Fig. 5, the second Atlas Burner and the last Burner 2 launch took aloft two radiation satellites on 2 October 1972 from WTR into polar orbit. Compare the heat shield with that used on the DMSP vehicle (Fig. 4).

US Air Force

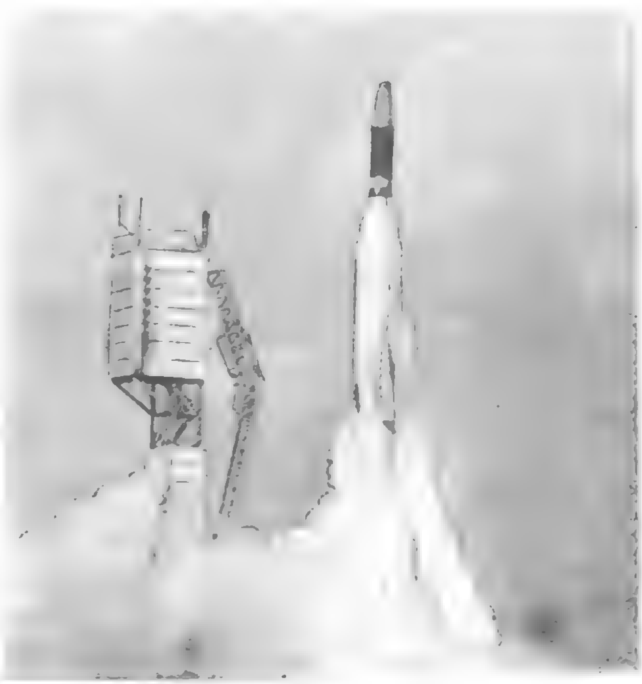
The reaction control system was essentially the same as in Burner 2 but because larger masses were being handled the four hydrogen peroxide thrusters were upgraded to 55 lbf (245 N) and their two supply tanks enlarged to 18 lb (8.2 kg) capacity. It has since been revealed, however, that guidance control during Block 5D launches was given by a reprogrammable computer aboard the *payload* because of the high accuracy needed. RCA claim this was the first use of such a system in unmanned launches [5].

The heatshield, as decribed for Burner 2, covered the payload and both stages. The basic structure of the stages had to be modified considerably because of the addition of an upper stage. Both stages used a basic hexagonal aluminium module with, on the upper stage, flight control modules mounted on the exterior. A triangular truss at the very top supported a three-point explosive separation system. Three primary beams ran the length of the stages to transmit loads to the first stage booster. With a diameter of 62 in (157 cm) and a height of 75 in (191 cm) from booster to payload interfaces, Burner 2A weighed 2484 lb (1127 kg) before lower stage ignition and 254 lb (115 kg) at upper stage burnout.

Burner 2A payloads were exclusively Block 5B and 5C DMSP satellites, covering 1971 to 1976. The first seven were all successful launches but the eighth and last in February 1976. The first saw the first failure. As in the previous Burner failure in 1968, the Burner stage itself was not to blame. On this occasion the Thor booster malfunctioned and the payload ended up in a 90 km perigee orbit and decayed soon after.

Other Burner payloads

Only four Burner flights carried non-DMSP payloads but even so they were Air Force-connected. The first, in 1967, was a



dual launch to orbit Aurora 1 and Secor 9, designed to investigate the Aurora Borealis and help in the determination of accurate ground station locations, respectively. The launch was part of the new AF Space Experiments Support Program (SESP). 0V5-8 in 1968 failed to reach orbit on the first Atlas Burner 2 because of the heatshield problems mentioned earlier. In 1971, another SESP satellite was launched to test an infrared celestial mapping sensor system. The last non-DMSP payloads were STP72-1 and Radcat launched together in 1972 as part of the Space Test Program (STP) which had taken over from SESP. STP72-1 was concerned with radiation investigations in Earth orbit while Radcat acted as a passive optical and radar calibration target.

Conclusions

In all, Boeing built fourteen Burner 2 and eight Burner 2A stages under five successive contracts totalling $29.6M over the period from April 1965 to April 1967. It saw its main use as an upper stage for the Thor vehicle but it was capable of being mated with the Atlas (two launches) and various configurations of Titan III and it was also the subject of several studies to extend its usefulness. For example, a 1968 Boeing study indicated an Atlas Centaur with a Burner 2 upper stage could place a 2000 lb (907 kg) payload in synchronous orbit or send 500 lb (227 kg) to Jupiter. Another study looked at the possibility of combining it with a Minuteman booster.

Acknowledgements

The author would like to thank William Rice (Boeing), Eugene Alberts (SAMSO), James B. Schulty (SAMSO) and Timothy C. Hanley (Chief, Office of History, SAMSO) for making this article possible.

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SOVIET RE-ENTRY TESTS: A WINGED VEHICLE?

By Trevor Williams

Introduction

Readers will be aware that the Soviet Union has conducted three mysterious one-orbit flights, Cosmos 881/882, 997/998 and 1100/1101 over the past three years. These missions have generally been assumed (see for instance [1] and [2]) to be man-related and connected in some way with the Soviet space shuttle programme, but this has never been proved: nor have observers been in agreement about the tests carried out. It is the object of this article to present strong evidence showing that these flights were in fact re-entry tests of a winged vehicle, and to give a brief outline of the probable mission profile.

Mission Profile

In summary, the three flights each consisted of two spacecraft being launched by a Proton launch vehicle into an approximately 210 km circular orbit of inclination 51.6°. Launch times were within about two hours of midnight GMT in each case, varying as shown in the table below (the last column is explained later), and the spacecraft were deorbited (assumed recovered) within one revolution.

Mission	Date of Launch	RAE Time of Launch (days, GMT)	Improved Launch Time (days, GMT)
C. 881/882	Dec. 15, 1976	0.07	0.065–0.066
C. 997/998	Mar. 30, 1978	0.00	0.004–0.005
C. 1100/1101	May 22, 1979	0.96	0.955–0.956

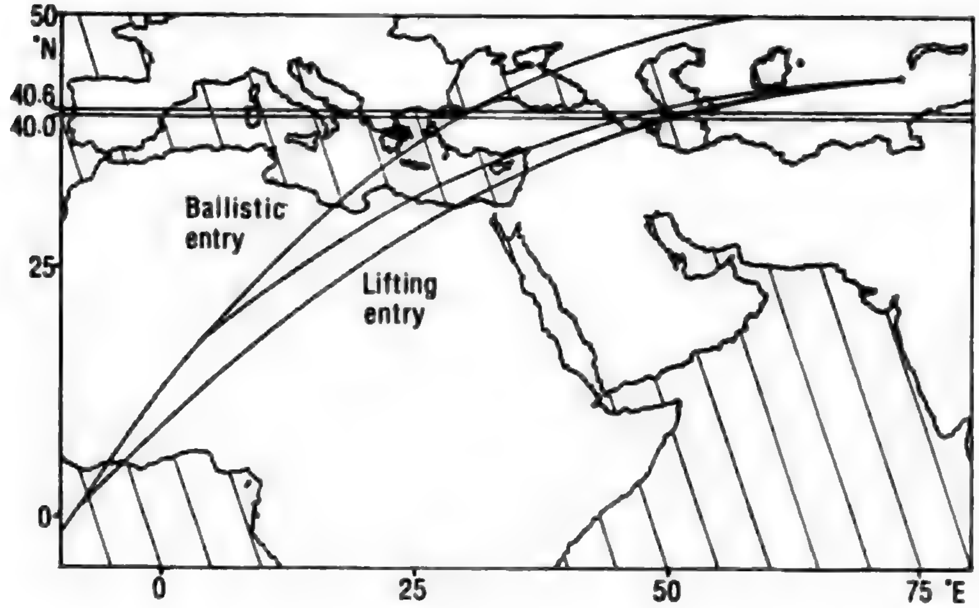
The very short flight durations strongly suggest that re-entry and/or landing tests were the primary mission objectives, as the ground-track of the 51.6° inclination orbit flown only passes over Kazakhstan on the first three revolutions of each day. Thus, if the vehicle tested is not equipped to survive a flight of as long as one day (as would be the case for a prototype re-entry vehicle), recovery must be attempted on the first few passes.

Furthermore, these launches all occurred at night, a fact which is hard to attribute to chance alone. It is therefore almost certain that these missions had some sort of launch window constraint. In addition, the December flight had the latest launch time and the May flight the earliest one, leading to the possibility that each launch took place at a fixed interval before dawn at some northern latitude. Indeed, it can be shown that certain latitudes satisfy this condition, and that they lie in the very narrow range from 40.0°N to 40.6°N. (These calculations are based on the times of launch given by the Royal Aircraft Establishment, quoted in [3], which are given to 2 D.P., i.e. to ±0.005 day = 7.2 min.) Sunrise at the meridian of Greenwich for these latitudes occurs 0.237–0.238 days (5 hr. 41–43 min.) after launch for all three missions considered here.

This result is interesting for three main reasons. Firstly, it obviously allows the time of launch for any further flights of this type to be calculated for a given launch date. For example, if the supposed Proton launch failure of 4 August 1977 mentioned in [4] was intended to be such a mission, launch would be expected at about 0.971–0.972 GMT.

Secondly, only certain launch times from the original RAE ranges satisfy the requirement that dawn (at 40.0–40.6°N) follow them by a fixed interval. This allows refined estimates of the actual launch times to be made: these are given to 3 D.P. in the last column of the table above.

Thirdly, and most importantly, this connection with dawn at the latitudes mentioned can be used to gain some insight into the mission profile flown. In particular, if we assume a Proton launch phase lasting 11 minutes and covering a range of 2500 km (typical values for a launch vehicle), the spacecraft cross the 40.3°N line at about 87 min. Ground Elapsed Time



Trajectories for ballistic and lifting re-entry into the Soviet Union.

(CET) and at a longitude of 29.6°E. Combining this with the delay estimated above places the crossings at about 136–138 minutes before local dawn, well before any appreciable daylight. We are thus faced with an apparent paradox, in that these flights are clearly keyed to dawn at certain latitudes and yet cross these same latitudes in darkness. Assuming mission durations of two revolutions instead of one does not resolve this, as the later crossings which result occur farther to the west, at the same local time as before.

The only way to solve this problem is to assume that the spacecraft have some means of travelling far to the east of their original ground-track, i.e. towards dawn. To achieve this in practice requires considerable cross-range manoeuvring during re-entry, probably of up to about 1000 km. This is well above the capability (less than 100 km) of offset centre-of-gravity re-entry vehicles such as Apollo and Soyuz, but less than the performance quoted for winged and lifting-body vehicles (e.g., 2040 km for the US Space Shuttle [5] and at least 2060 km for the Aerospatiale Hermes design study [6]). It is therefore highly probable that the spacecraft flown on these Cosmos missions are lifting-bodies or winged, and so are almost certainly prototypes of the Soviet shuttle vehicle whose drop tests were revealed by *Aviation Week & Space Technology* [7].

Recovery Zone

As noted previously, the short lengths of these flights point towards their being re-entry tests. This identification is supported by the connection with dawn established above, as such timing causes the early entry to be in darkness (enabling flames, ionization plume, etc., to be clearly visible) and the later part to be in daylight (so that the spacecraft can be photographed in flight). Such lighting is roughly ideal for a re-entry test flight. It is unlikely that a landing at Tyuratam would be attempted on these early development flights, due to the danger involved if anything were to go wrong: in any case, the new shuttle runway there was reported as being still under construction in early 1979 [8]. Some other suitable recovery zone must therefore be chosen: this should preferably be relatively flat and sparsely populated, should yield a re-entry path as much over Soviet territory as possible (to facilitate tracking), and should of course be reachable with the cross-range capability assumed. One such area is located at about 44°N×73°E in Peski Muyunkum, a small sandy desert lying south-west of Lake Balkhash in eastern Kazakhstan.

In order to complete this analysis we shall have to make two further working assumptions: these are that the re-entry trajectory flown follows a Great Circle route from Entry Interface (EI) to landing (probably a fairly good first approximation), and that the total range covered is between 6950 km and 9050 km (as compared with the US Space Shuttle range of 8150 km on its first flight [9]). On the basis of these, the spacecraft cross the 40.3°N latitude line at a longitude of from 46.2°E to 50.8°E (see figure) and at about 89 to 91 min CET, probably shortly before the end of radio blackout. Combining this with the delay between launch and dawn obtained above gives a crossing at 48 to 67 minutes before local sunrise, approximately at the time of first appreciable daylight.

Conclusions

In summary, the three Cosmos flights investigated were almost certainly re-entry tests of a lifting-body or winged vehicle, probably the re-usable Soviet shuttle speculated on elsewhere. Aircraft-type horizontal landings are not thought to have been included on these tests, as the most probable recovery zone (a desert in eastern Kazakhstan) is unlikely to be equipped with a suitable runway. Future unmanned flights culminating in landings at Tyuratam should be expected: note that such flights will not have launch times given by the relationship outlined above.

Finally, it is still not clear why two spacecraft were flown on each mission, or whether only one or both of these were winged.

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ERNST LOEBELL (1902-1979)

By Frank H. Winter*

On 19 September 1979 Ernst Loebell, German-born founder of the Cleveland Rocket Society of the 1930s and active rocketry experimenter during those years, died in Brentwood Hospital, Cleveland, of a heart attack.

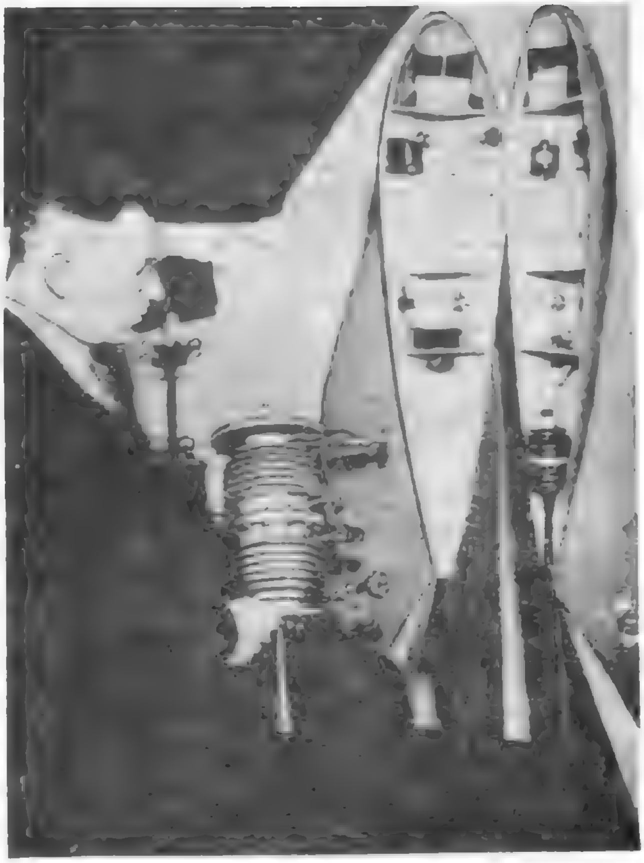
Loebell was born on 23 October 1902 at Zwingenberg, Hessen-Darmstadt, Germany. As a young man he was very interested in rockets, particularly the experiments of Fritz von Opel and Max Valier with rocket cars and planes, conducted during the late 1920s in Germany. Contrary to several published accounts, however, he did not become a member of the German Rocket Society (the Verein für Raumschifahrt), formed in 1927; neither did he conduct experiments for them. As a mechanical engineering student at the Hindenberg Akademie, Oldenburg, he engaged classmate Karl Poggensee in many technical discussions on rockets. Poggensee in 1931 launched one of the earliest instrumented solid propellant rockets which carried a radio transmitter and a camera.

Following graduation from the Academy in 1929, Loebell was hired by the Otis Elevator Company's Berlin branch as an engineer. As his thesis had been on "Henry Ford and his Work," Loebell was assigned to Otis's headquarters in Yonkers, New York. The young engineer shortly moved to Cleveland which became his home for the remainder of his life. Loebell first worked for the White Motor Company in this city but due to the Depression could only work sporadically, at various engineering firms.

In January 1933 the Cleveland Engineering Society requested him to present a lecture on the future of rocket travel for their Technicraft Show. Loebell consented and included a model of a futuristic inter-continental mail rocket. Edward L. Hanna, a licensed aeroplane pilot and wealthy grandson of the famous Ohio politician Marcus Alonzo Hanna, was very impressed with Loebell's presentation and convinced him to begin a Society devoted to the development of this transportation of the future. Consequently the Cleveland Rocket Society was formed with a handful of people and some financial assistance from Hanna.

A rocket laboratory and test stand was established on the Hanna estate near Cleveland while the Hanna Building in downtown Cleveland served as Society headquarters. Hanna also assisted in the printing of the Society's mimeographed journal *Space*. By the summer of 1934 membership amounted to 50. Hundreds of letters were received from the United States and abroad and considerable interest in the group was generated in the press. Movietone-News filmed some of the tests. Loebell was also made an Honorary Fellow of the British Interplantary Society.

Several liquid oxygen-gasoline engines were static fired at the Society's test facility which the June 1936 issue of the *Journal of the British Interplanetary Society* called "one of the best-equipped rocket testing grounds in existence". The experiments were very primitive by today's standards, however. Thrusts for CRS motors averaged about 30 lb (14 kg). Ignition was first accomplished by a blowtorch; later spark plugs were used. The fuel was either injected into the combustion chamber by the pressure of the liquid oxygen or by nitrogen pressurization. No flights were ever made. There was a chronic shortage of funds to continue the tests. Nonetheless, Loebell designed and built two comparatively large, 18 in (7 cm) long regeneratively-cooled motors which he calculated would deliver 5,000-7,000 lb (2,268-3,175 kg) thrust. While these motors were never fired, Loebell preceded the American James H. Wyld by three years in the design and construction of the regeneratively-cooled system.



Ernest Loebel, Chief Engineer of the Cleveland Rocket Society, holds a "third series" CRS rocket motor. Alongside is a model of the rocket which the CRS planned to build. Both were sent to the Paris International Exhibition of 1937.

Archive of Contemporary Science and Technology Case Institute of Technology

One of these motors was exhibited at the International Exposition in Paris in 1937 and was viewed by Charles A. Lindbergh. A specimen of the motor can be seen today in the Neil Armstrong Museum, Wapakoneta, Ohio.

Unemployment and the shortage of funds caused the demise of the Cleveland Rocket Society by 1937-1938. At about the same time Loebell became associated with the inventor-industrialist, William P. Lear of Learjet fame. He worked for the Lear Company as a stress and gear analysis engineer until his retirement in 1968, after 26 years of service. Loebell still kept an active interest in rocketry, and especially spaceflight achievements and presented several talks before Cleveland organizations on space developments and the need for public support of the US space programme. His own achievements did not go unnoticed and he was at one time honoured by the US Air Force with a special luncheon at Wright-Patterson Air Force Base, Dayton, Ohio. Loebell was to have presented a memoir paper at last year's International Astronautical Federation History Symposia in Munich, West Germany, but was unable to do so because of illness.

Loebell is survived by his American-born wife, Lucile, and their daughter, Hildegarde, of Detroit.

* *National Air and Space Museum, Smithsonian Institution, Washington, D.C.*

SKYLARK SOUNDING ROCKET FACILITIES FOR MATERIALS SCIENCE EXPERIMENTS

By D. J. Brown*

Introduction

The increasing interest among materials scientists in carrying out experiments in a space environment which has followed in the wake of the experiment results from Apollo, Skylab, Apollo-Soyuz and other missions, suggests the need for an interim research facility before the introduction of the NASA Space Shuttle in the 1980's. Sounding Rockets that have reached a high level of reliability as a result of many years of service in other scientific fields are a ready-made tool for this purpose. They can provide useful periods of microgravity conditions for many types of experiment.

The Skylark sounding rocket, which is a product of British Aerospace (BAe), has recently been employed successfully in this role. It has been selected for the German Federal Republic materials science programme TEXUS. This programme was initiated in order to flight prove experiments in advance of the ESA Spacelab missions. The flight results to date have shown that this approach was justified both on scientific and technological grounds.

With the launch of the first ESA Spacelab nearly three years away[1] and Skylark flights available with a short lead time, it is worthwhile materials scientists seriously considering the benefits of using Skylark in order to prove and refine their experiments and so gain maximum benefits from Spacelab missions. Alternatively, Skylark can be used for materials science experiments in their own right. In either case, a cost of around £1,500 per kilogram of experiment module mass is achievable based on sharing the total vehicle and launch costs (but excluding experiment module costs) for a nominal payload mass of 350 kg. By launching from a land range such as EsRange (Kiruna) or Woomera, Australia, the payload can be recovered and re-used.

This paper describes the Skylark vehicle most suitable for microgravity missions together with the payload support hardware that BAe can provide. Also outlined are the plans by BAe to utilise Skylark technology for Shuttle small self contained (Getaway Special) payloads.

Skylark Vehicles

A sounding rocket consists essentially of two distinct parts, the propulsion stages or motor kit, and the payload. The following information is a brief outline of the main features and performance characteristics of the two Skylark vehicles particularly suited for materials science experiments.

Vehicle Configurations

The Skylark family of sounding rockets is based on a highly reliable series of flight proven 0.44 m diameter, solid propellant motors which are manufactured in Great Britain. Over 370 Skylarks have been launched from launch sites in Australia, Sweden, Norway, Spain, Italy and the Argentine with an overall reliability of at least 95% for the motor kit.

The current Skylark vehicle most appropriate for materials science experiments is the Skylark 7, shown in Figure 1, which is already being used for the TEXUS programme. Skylark 7 consists of a Goldfinch boost which burns for 5 secs before it is jettisoned and a Raven XI sustainer motor which burns for a further 39 secs. A canted fin unit, which produces a nominal vehicle spin rate of 3 revs/sec, if fitted to the sustainer in order to provide stability during flight without recourse to an active guidance system. Small spin-up motors are fitted to the boost in order to limit impact dispersion.

An attachment ring containing the sustainer motor ignition unit and a payload despin/separation system is attached to the forward end of the Raven motor. The payload is normally

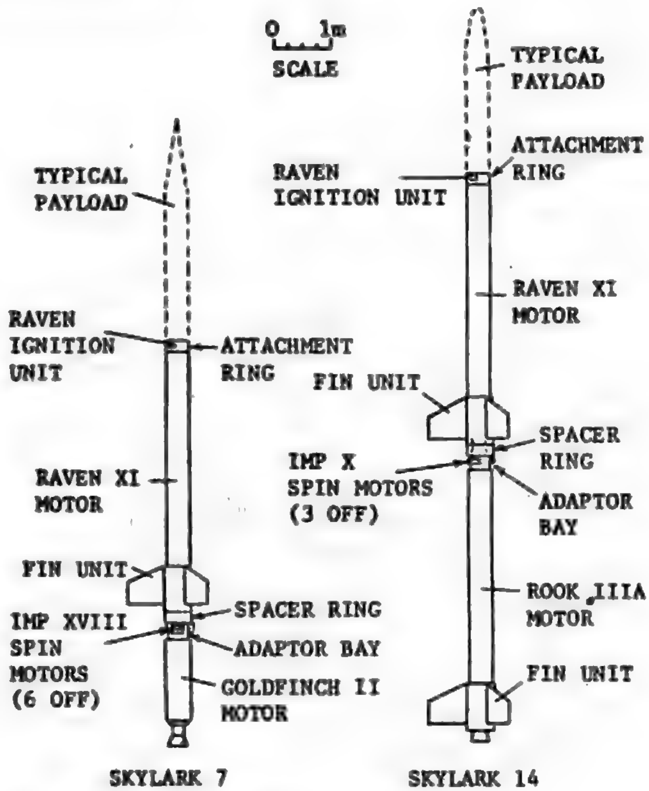


Fig. 1. Skylark Vehicle Configurations.

separated from the motor at between 70 and 80 km altitude after first being de-spun by a "Yo-Yo" system.

The most recent addition to the Skylark family is the projected Skylark 14 vehicle, also shown in Figure 1. By replacing the Goldfinch with a more powerful boost motor, called Rook, the microgravity time, or alternatively the payload mass capability, is increased. Except for the addition of another fin unit on the boost this vehicle is virtually identical to the Skylark 7 and employs the same flight sequences.

Flight Environment

The main features of the flight environment provided by Skylarks 7 and 14 are as follows. Reference is made to the predicted Shuttle/Spacelab environment where appropriate in order to provide a means of comparison for experimenters who have designed experiments for Spacelab.

Launch Acceleration

Figure 2 shows axial acceleration versus flight time for both vehicles. Although higher than for Spacelab, linear accelerations of the levels shown are not normally a critical factor for the majority of experiments; vibration usually represents a more severe test. It should also be borne in mind that experiment equipment used on Spacelab must anyway be designed to withstand the Shuttle emergency landing case.

Flight Vibration

Figure 3 shows the Random Noise vibration levels for both Skylark vehicles. Also shown for comparison are the predicted levels for the empty Orbiter. It is recognised that the levels inside the Spacelab module will be much less than for the empty Orbiter but a comparison cannot be readily made based on the information given in Ref 2. However, it is reasonable to conclude that Skylark levels are probably higher at the higher frequencies and Spacelab levels are higher at the lower frequencies.

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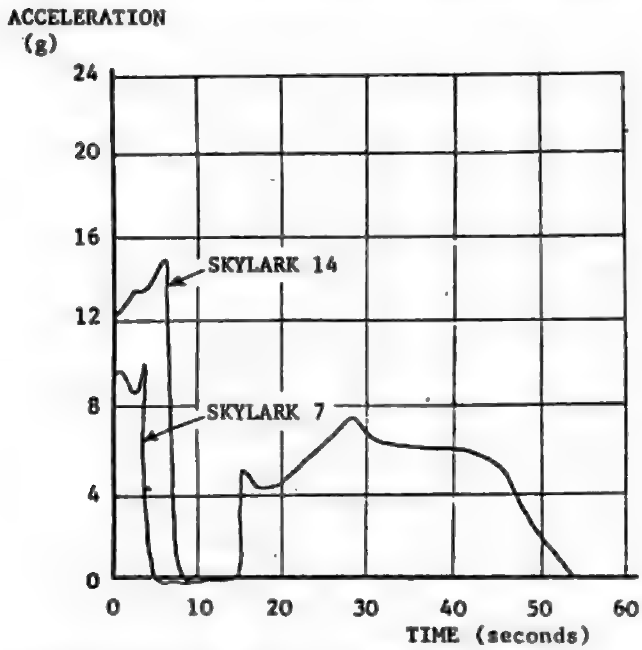


Fig. 2. Skylark Vehicle Acceleration Profiles.

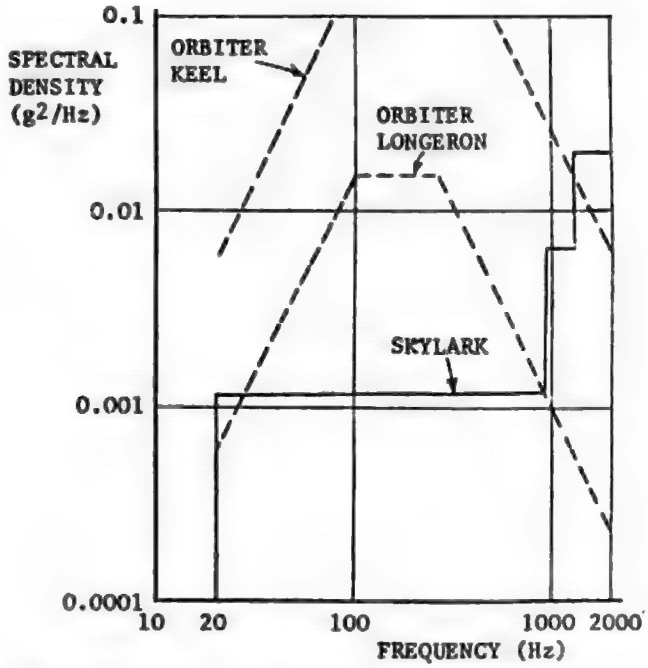


Fig. 3. Skylark Vibration Levels.

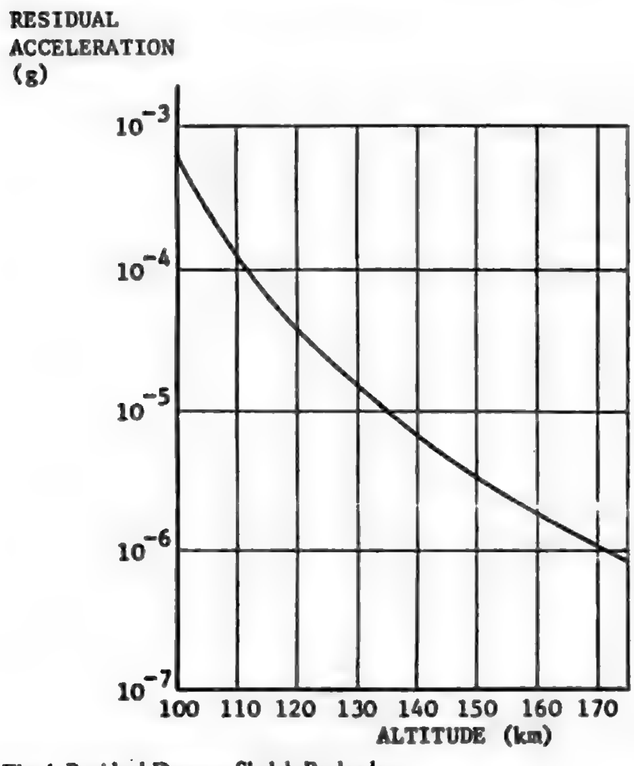


Fig. 4. Residual Drag on Skylab Payloads.

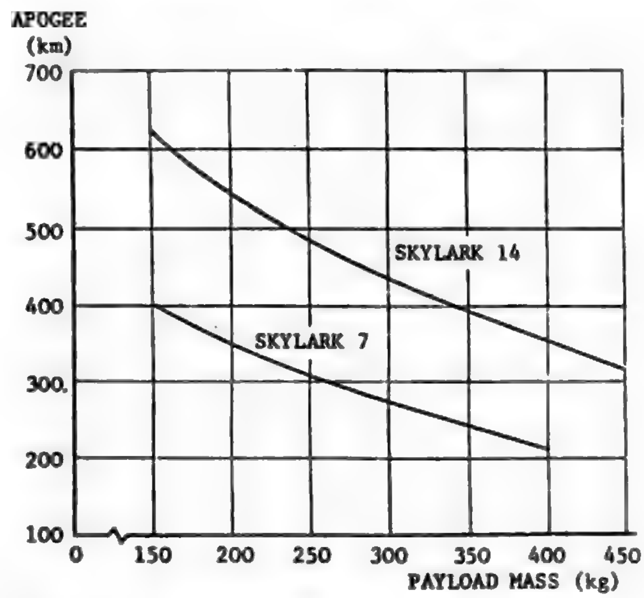


Fig. 5. Skylark Apogee Performance.

Microgravity Period

For a sounding rocket, the zero-g condition is approached during the ballistic part of the flight when the payload is in a free fall condition and only subjected to the effects of atmospheric drag and any pulses from an on-board rate control system.

Figure 4 shows a curve of residual acceleration up to 170 km altitude for both Skylark 7 and 14. It can be seen that the level reaches 10^{-}g by 112 km and continues to reduce thereafter. By comparison, the Orbiter acceleration level on orbit during a passive gravity-gradient stabilised mode can be up to 10^{-4}g[3].

In order to maximise the use of the microgravity period it is possible to switch on furnace experiments at or just before the launch of a Skylark.

Performance

The apogee performance is shown in Figure 5 for differing payload masses although this criterion is probably not of direct interest to materials scientists. However, the allowable apogee, and hence microgravity time, may be limited at particular ranges in order to satisfy dispersion requirements. For example, the allowable peak apogee for Skylark 7 launched from the Kiruna tower is currently 348 km and so the minimum payload mass is 220 kg.

Figure 6 shows plots of experiment times at an acceleration level of 10^{-4} g or less for a range of payload masses. These curves indicate that almost 6 minutes is provided by Skylark 7 for a 350 kg payload and, in fact, this performance has been confirmed by the TEXUS I & II launchings. Skylark 14 can provide over 8 minutes for the same payload or 7 minutes for a payload of 450 kg.

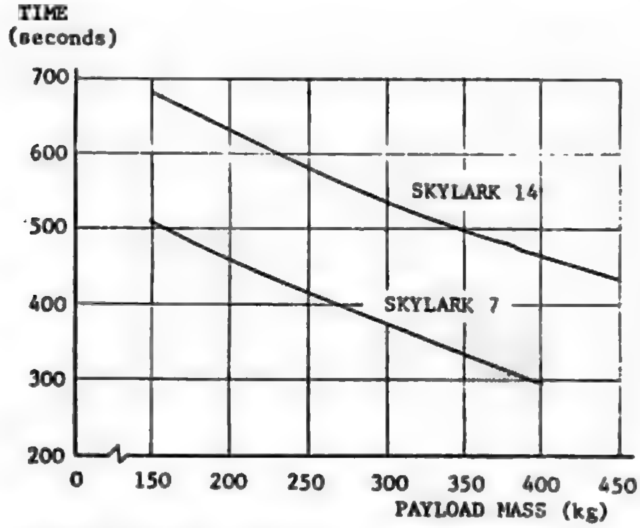


Fig. 6. Skylark Experiment Time at 10^{-4}g.

Payload Equipment

For many years the Skylark motors have been supplied to users who have preferred to design and fabricate their own payloads. This is the method employed for the TEXUS programme. However, BAe have a long experience of designing payloads and can therefore offer basic payload hardware, subsystems and experiment modules as required by a user.

Hardware and Subsystems

The Skylark payload sections have been designed to be modular so as to facilitate the construction of a wide range of payloads in a cost-effective manner. This approach also enables experimenters to have maximum freedom in building their own experiment sections.

A standard range of 0.44 m diameter magnesium alloy payload sections ranging from 0.20 m to 0.50 m in length is available (Figure 7). These can be employed for individual experiment modules or payload systems and are fitted together very simply by means of quick release manacle clamp rings.

Standard bulkheads which fit into the ends of payload sections can be used for mounting equipment.

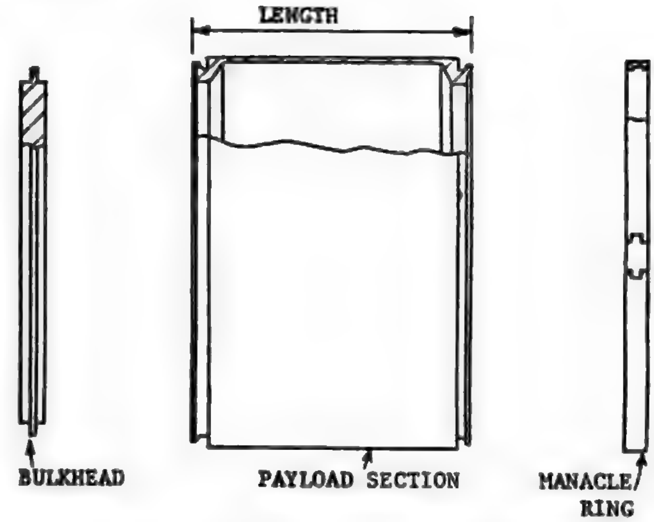
Other standard payload equipment that can be made available are as follows:

- Nose cones of different types such as pointed and rounded tip versions.
- Telemetry systems suitable for a range of operating frequencies.
- Event timers.
- Rechargeable power supplies which can provide a range of voltages and power.
- A rate control system based on a Skylark system used for Earth survey experiments.
- A Recovery Bay which has a current recovery rating of 260 kg that can be readily uprated to a capability of 350 kg.

Experiment Modules

BAe are currently engaged on a proposal for the Fulmer Research Institute to accommodate isothermal and radiant furnaces in a Skylark payload section.

As an example of work already carried out, BAe prepared a layout for an electrophoresis experiment as part of an ESA study[4]. This is shown by Figure 8 which illustrates the way in which a standard Skylark payload section and mounting bulkheads can be used.



ITEM	LENGTH (mm)	MASS (kg)
PAYLOAD SECTION	203	4.5
PAYLOAD SECTION	305	5.9
PAYLOAD SECTION	406	7.2
PAYLOAD SECTION	508	9.0
BULKHEAD	25	3.8 or 5.5
MANACLE RING	-	1.0

Fig. 7. Skylark Module Hardware.

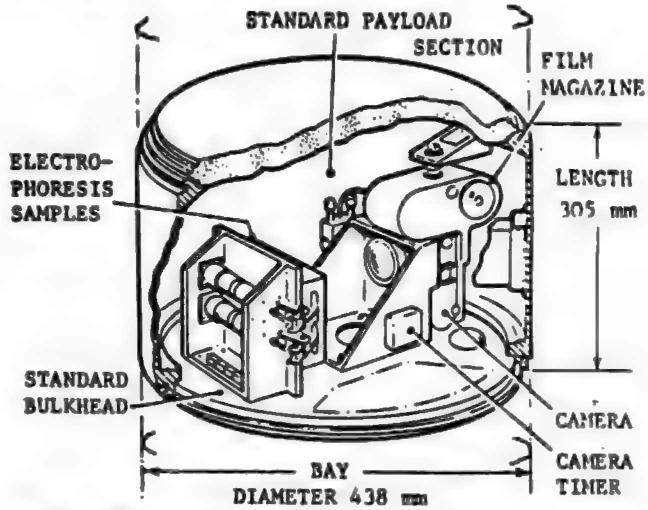


Fig. 8. Electrophoresis Module.

Payload Length

As a general guide for preliminary planning purposes Figure 9 shows curves of allowable payload length against payload mass for Skylark 7 and 14. This requirement ensures that the vehicle maintains aerodynamic stability during its flight through the atmosphere. The curves shown are based on a payload comprised of Skylark payload sections and nose cone and assume a centre of gravity position at 40% of overall length measured from the payload aft end, which is typical for actual payloads.

Launch Range Operations

Skylark 7 and 14 vehicles can be launched from the 30 m tower launchers installed at the Woomera and Kiruna launch ranges and also from suitable single beam launchers such as the DFVLR MAN launcher.

Recovery of the payloads can be accomplished within 1 to 2 hours from launch as demonstrated by the TEXUS launchings. Experiment samples can then be returned to experimenters very quickly and so facilitate rapid analysis.

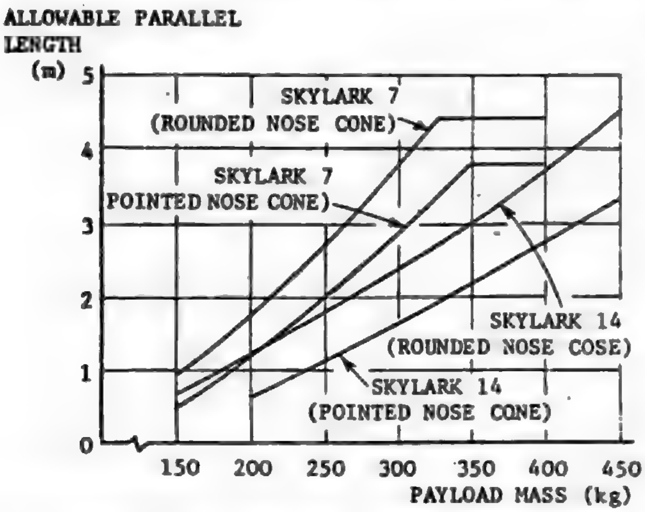


Fig. 9. Nominal Payload Length/Mass Limitations.

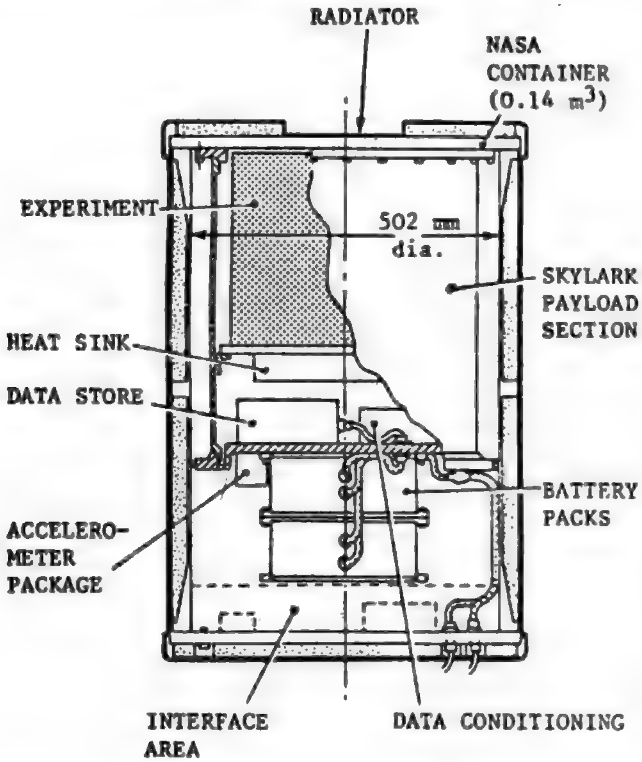


Fig. 10. Typical Microgravity Payload in GAS Container.

Small Self-Contained (Getaway Special) Payloads For Shuttle

The announcement by NASA for the provision of Getaway Special (GAS) payloads on Shuttle flights at a nominal launch charge is encouraging for a wide range of experiments. It is particularly relevant for materials science experiments that are not large, do not require lengthy operating periods and are virtually fully autonomous. This approach is therefore consistent with sounding rocket practice and so it is logical to utilise sounding rocket components for this role [5]. In addition, the use of the GAS facility provides the possibility of longer experiment times than is possible with sounding rockets.

A feature of GAS payloads is the frequency of flight opportunities when compared with Spacelab. It is understood that NASA propose to accommodate an average of four GAS payloads per Shuttle flight although there will be missions which will not be suitable for microgravity experiments.

In order that GAS flights and sounding rocket flights can be complementary it is desirable to design experiment modules that can be readily flown on either. Although a GAS payload flight should provide a microgravity period of around an order greater than a Skylark flight, the experiment mass carried will be correspondingly less.

GAS Payload Constraints and Facilities

The Orbiter will not provide power, data storage, thermal control or timing facilities for GAS payloads[6]. However, up to 3 "on/off" commands will be provided by means of an Autonomous Payload Controller operated by the crew. This command facility can be used to initiate materials science experiments during a low acceleration period on orbit (subject to negotiation with NASA). In addition to the experiment commands, there will be an additional mandatory command link to all GAS payloads to enable the crew to simultaneously de-activate and make safe all these payloads in the event of an emergency situation arising.

The GAS containers are supplied on loan by NASA, are cylindrical in shape and can be either pressurised up to 1 atmosphere or evacuated as required. They are available in three sizes, each one restricted to a maximum experiment mass that can be carried, as follows:

Volume m^3	*Allowable Mass* kg
0.14	90.9
0.07	45.4
0.04	27.3

Access to GAS payloads will be restricted for a period of time immediately before launch. Although not yet finally specified by NASA, this period could be several weeks and should be taken into account for experiments as well as the support equipment.

GAS Payload Configuration

BAe have produced an experiment module configuration which is suitable for the largest NASA container (the most cost effective) using Skylark components wherever possible.

Figure 10 shows the arrangement for a typical materials science experiment such as the furnace proposal mentioned earlier (or the electrophoresis experiment shown in Figure 8). The support equipment shown can be selected from a standard support kit consisting of the following items, some of which are optional.

Structure

A Skylark payload section is used as the basic support structure since it provides the sounding rocket/Shuttle interchangeability previously mentioned. It also provides an ideal interface with the GAS container in terms of size and shape. The platform attached to the base serves to mount support equipment and also obtains lateral support from the container inner wall.

Power Supply

A BAe battery box, designed for a subsatellite application, is a sealed container which can accommodate different types of cells such as Nickel/Cadmium or Silver/Zinc (used for sounding rocket payloads) or Lithium (which have yet to be approved by NASA) providing 220, 420 or 1000 Wh respectively. The battery packs can be stacked to provide the required power.

Data Store

For certain experiments it may be required to store in-flight data. This can be achieved by use of a suitable tape recorder or, alternatively, an electronic memory can be utilised. BAe are currently studying the application of bubble memories to this role in view of their inherent flexibility which enables them to be matched to particular requirements for storage capacity. Data conditioning electronics are used to multiplex

experiment outputs and modify the signals into the correct format for suitable recording.

Programme Timer
In addition to the commands provided by Shuttle it may be necessary to initiate various experiment events and this can be achieved by including a programme timer in the payload. The timer available is an electronic device which has already been flight proven on Skylark.

This timer has a basic facility for up to twelve on/off relay events and the duration can be varied over a wide range by using a crystal oscillator with a chosen frequency and by changing the number of binary divisions between the oscillator and the counter.

Accelerometer Package
NASA will provide post flight information on the orbit and attitude of the Orbiter during the experiment periods but not necessarily the actual microgravity levels. If this information is essential to the experiment an accelerometer package can be included in the support equipment. Accelerometers can be provided which can measure to an accuracy of $\simeq 5\times10^{-5}$g in all three axes.

Thermal Control System
Thermal control of the experiment and support kit demands special attention in view of the extremes of temperature to which the container can be subjected, depending upon the mission. Another factor to be considered is the amount of heat energy dissipated by furnaces which may involve restricting the experimentation period to coincide with a favourable Orbiter attitude with respect to the Sun.

Since the container lid should always be pointing out of the Orbiter cargo bay it is appropriate to use the top surface as a radiator for the hot condition and to provide heaters to meet the cold condition. In addition, it may be necessary to include a heat sink such as a container of phase change material. In this way a temperature environment in the range 0 to +°C can he provided using a total heater power of not more than 100 Wh for a non-extreme mission.

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5. *The Application of Skylark Technology to Shuttle Payloads*. D. J. Brown. British Aerospace Dynamics Group. Paper presented at the 5th AIAA Sounding Rocket Conference, Houston, Texas, March 7-9, 1979.
6. *Getaway Special (GAS) Small Self-Contained Payloads Experimenters Handbook*. NASA Goddard Space Flight Center, December 1978.

A missed opportunity? Skylark 7 rockets being used for the TEXUS (Technological Experiments Under Microgravity) programme are preparing German technology and industry for the unique opportunities that will be available when Space Shuttle flights begin. Microgravity conditions allow research into new high strength alloys, some of which will not mix on Earth, new crucible-free melting techinques for super-pure alloys, fluid dynamics, physics and chemistry generally, So far no similar programme has been adopted in Britain. The first TEXUS flights with Skylark rockets took place in December 1977 and November 1978. TEXUS 3, 4 and 5 were scheduled in April 1980, April 1981 and September 1981. TEXUS 6 and 7 are planned. In addition to the German experiments, sections of certain payloads were prepared by the Swedish Space Corporation which contained experiments designed by the Swedish Royal Institute of Technology. As we closed for press we were informed that British Aerospace has decided not to proceed with the development of Skylark 14 because it is uneconomical to offer such hardware on the basis of small volume production. Ed.

COST OF THE SHUTTLE

By Gordon L. Harris

Introduction
Sharply increased costs of the Space Shuttle, expected to run over $8,000 million in all, are creating a serious imbalance in the US programme through 1981.

While President Carter's new budget provides $5,700 million, or $450 million more than 1980, nearly half the NASA outlays will be spent on Shuttle development and production. The reusable vehicle is now in its ninth year and has yet to fly.

Funding for space science and applications amounts to slightly more than $1,000 million or less than 20 per cent of the budget. Only three new starts are funded: a gamma ray observatory to identify high energy sources, an operational land observing system and an oceanic satellite shared with the Departments of Defense and Commerce.

Meanwhile the agency will launch only five missions in 1980, two commercially sponsored and a third a military satellite. Only two flights involve scientific interests, a solar observatory and a geostationery environmental satellite for the National Oceanic and Atmospheric Administration.

NASA Administrator Robert Frosch labelled the 1981 budget "positive" and a "good beginning for the decade of the Eighties." A cursory examination of the figures, however, revealed that the agency is caught up in a tight squeeze while it struggles to complete the reusable Shuttle. In addition to increasing expenditures next year, the budget anticipates $300 million more than budgeted for Shuttle work in 1980. Frosch said "we must have those funds not later than 1 June."

President Richard Nixon kicked off Shuttle development in 1972 when NASA estimated its cost at $5,200 million and forecast a first manned launch late in 1978. Overall costs passed the $7,000 million mark with "Columbia", the first orbiter, still in a Kennedy Space Center hangar. Frosch suggested the initial launch may occur late this year; if not, the budget includes sufficient funds to continue work into the Spring of 1981.

The "most worrisome" problem, the NASA Administrator said (26 January 1980), concerns Orbiter's thermal protection system (see *Spaceflight* Vol.21, No.12 December 1979) consisting of 31,000 tiles applied to the outer skin which protect ship and crew from re-entry heating in excess of 2,500 degrees F. Tile installation was to have been completed in November 1979 under a revised work schedule. It is still incomplete (late January 1980).

Astronauts and flight controllers put "Columbia" through simulated liftoffs and landings with minor equipment problems in December 1979 and January 1980, but even as these tests proceeded NASA exhibited new concern about the heat insulation. Doubt has been expressed as to the system's integrity and endurance under flight stresses. Up to 7,000 tiles may have to be removed and re-applied.

Loss of Shuttle Customers
Delays are beginning to cost NASA the loss of some potential Shuttle customers. Without identifying them Frosch acknowledges that two "users" have turned to the ESA Ariane booster, unable to wait any longer for an operational Shuttle. On the bright side of an otherwise confusing picture, NASA claims it has turned the corner on Shuttle engines and they stood up well in recent "hot" tests.

In lieu of Shuttle, the agency will continue to fly Scout, Delta and Centaur boosters. Three Centaurs are scheduled in 1980: one for a Defense communications satellite managed by the US Navy, and two for a new series of high capacity satellites for the 102-member International Telecommunications Satellite Organization. Delta will boost SMM-A, a NASA spacecraft to study solar flares, sunspots and other activity on the Sun's surface, and GOES-D, the meteorological and oceanographic data collector for NOAA.

Because it now hopes to fly Shuttle within the next 15 months, NASA cut funding for expendable vehicles in its 1981 budget from $70.7 million this year to $55.7 million next. Centaur money drops from $18.3 million to $5.6 million while Delta increased slightly to $47.9 million, possibly insurance against more Shuttle delay.

Reversing a trend of several years, President Carter did not cut NASA manpower which will rise to 22,713 or 100 more positions. That change in direction, Washington observers noted, was influenced by the fact that 1980 is Election Year.

The budget also suggests that the cost of sustaining the NASA establishment consisting of Washington headquarters and 10 field installations continues upward. It requires $1,040 million in 1981 or about one-fifth of the total budget.

Space Science and Applications

In space science projects, the budget carries on development for an international solar polar mission at $82.6 million; the large space telescope at $119 million, development of a second Spacelab, $72 million and the Explorer series, $33 million. The lone planetary project, Galileo, will continue at $63 million while $19 million supports life sciences flight experiments.

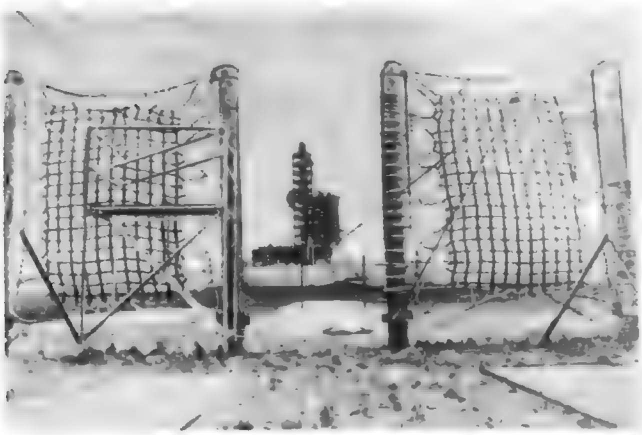
Space applications costing $381.7 million include continued work on Landsat D, magnetic field satellite, Shuttle payload development, Earth radiation budget experiment, halogen occultation experiment, and a search and rescue satellite based system.

The budget allocates $290 million for aeronautical research and technology and $115 million for space research and technology base. Energy technology receives $4 million.

Costs of NASA's space tracking and data systems increased again to $359 million, most of which supports day-to-day operations.

With publication of the President's budget 28 January came a warning to NASA from Chairman Don Fuqua of the House of Representatives Space Committee.

"We don't want NASA to ask for any more supplemental money for Shuttle," he declared.



KENNEDY SPACE CENTER. The Emergency Exit System (slidewire) at Launch Complex 39A providing a rescue capability for Shuttle Astronauts and Launch Crews. The journey along the 1,200 ft (365 m) wire would take approximately 35 seconds.

Photo: Stephen Smyth

SHUTTLE ORBITER. With the three main engines installed, work continues at the Kennedy Space Center on fitting and checking Columbia's "outer skin" of thermal tiles designed to protect the craft against re-entry heating. The task has proved much more formidable than expected.

NASA

BIS Council Elections

In the recent Elections to the Council the Report of the Scrutineers states that the total number of voting papers submitted up to and including 31 January 1980 was 1032. The number spoiled was 2.

The names of the Candidates and the number of votes cast for each were as follows:

Position	*Name*	*Number of Votes*
1.	K. W. Gatland	974
2.	G. M. Webb	888
3.	P. J. Conchie	845
4.	L. R. Shepherd	825
5.	W. R. Maxwell	710
6.	I. G. MacKinlay	336
7.	J. I. Stone	210
8.	F. R. Smith	119

The five Candidates receiving the highest number of votes were declared elected.

Mis-named. We owe Mat Irvine, who performed such noble service for the Society at the 37th World Science Fiction Convention in Brighton, an apology. Somehow his name was rendered in the printed version of our report (*Spaceflight*, February 1980, p. iii) as Matt Irving (no, it wasn't another fella! Ed).

1980 LAUNCH SCHEDULE

The first launch of the Space Shuttle had been targeted for 30 June 1980. Achieving this goal depended on the following events at the NASA Kennedy Space Center, Florida:

- Late March 1980 – Rollout of orbiter Columbia from the Orbiter Processing Facility to the Vertical Assembly Building.
- Mid-April 1980 – Rollout of the complete Shuttle stack (orbiter, solid rocket boosters and external tank) from the Vertical Assembly Building to Launch Pad 39A.
- Mid-May 1980 – Conduct a Flight Readiness Firing (a 20-second firing of the Shuttle main engines on the launch pad).
- June 30, 1980 – First flight of the Space Shuttle.

Another milestone that had to be met to achieve the launch date goal was Space Shuttle Main Engine Certification scheduled for 30 June 1980.

Although NASA was working toward this end-of-June launch date, Dr. Robert A. Frosch, NASA Administrator, had emphasized that "sometime in August or September is a much more likely launch date" since problems unknown at this time could cause further delays.

In other 1980 activities, NASA plans a total of nine unmanned launches, eight of which will be reimbursable services for other organizations.

Launch	Mission	Vehicle	Site	Description
January 1980	FLTSATCOM	Atlas Centaur	ESMC	DOD – Communications Reimbursable.
January 1980	SMM-A	Delta	ESMC	NASA – Scientific Solar Maximum Mission.
February 1980	Intelsat 5A	Atlas Centaur	ESMC	Intelsat – Communications Reimbursable.
April 1980	NOAA-B	Atlas-F	WSMC	NOAA – Weather Reimbursable.
May 1960	Intelsat 5B	Atlas Centaur	ESMC	Intelsat – Communications Reimbursable.
July 1980	Navy-20	Scout	WSMC	DOD – Transit Reimbursable.
August 1980	GOES-B	Delta	ESMC	NOAA – Weather Reimbursable
August 1980	Intelsat 5C	Atlas Centaur	ESMC	Intelsat – Communications Reimbursable.
October 1980	Navy-21	Scout	WSMC	DOD – Transit Reimbursable.

STARLINK

The Science Research Council is to set up a network called "Starlink" of six "supermini" computers for astronomical image and data processing at a capital cost of £1.8M.

UK telescopes are producing vast amounts of data of the highest quality. Even more data will be produced by the SRC telescopes being erected on La Palma in the Canary Islands, and by use of the Space Telescope but there have hitherto been very limited facilities for performing scientific analysis of these observations. Astronomers have either to reduce the data manually or devise their own image and data processing facilities on an ad-hoc basis. Even those modest facilities which exist can only be used by a few astronomers and they are heavily over-subscribed. In the 1980s the vast majority of astronomy will be done using data in digital form and adequate image processing facilities will be required. Starlink is SRC's response to these problems and in line with its policy to maintain the UK in the forefront of astronomy.

The computers – VAX 11/780s – will be located at Cambridge, University College London, Manchester, the Royal Greenwich Observatory, the Royal Observatory Edinburgh, and the site of the combined Rutherford and Appleton Laboratories at Chilton near Oxford. Each computer will support two sophisticated image display systems in addition to graphics and alphanumeric Visual Display Units. They will be connected by communications links to Chilton where the networks will be managed and systems software developed. The system will provide a user facility for all. Sixty per cent of our astronomers will have access to a terminal on the spot and a further 20 per cent will be within three quarters of an hour's travel of one. The Council has also agreed in principle to add an ICL Distributed Array Processor (DAP) to Starlink later subject to availability of funds and the outcome of trials with the Queen Mary College DAP installation.

Starlink was first proposed by an SRC Panel on Astronomical Image and Data Processing under the Chairmanship of Professor M. J. Disney (Cardiff). The Panel analysed the types and volumes of image data to be expected by astronomers, the needs and distribution of working astronomers, the problems of software sharing, and several models for computer provision.

ARIANE FLIGHT CONTROL

From the moment Ariane lifts off from the Guyana Space Centre, it is controlled by the flight programme developed and produced by Marconi Space and Defence Systems.

After launch Ariane is completely autonomous; the only possible intervention from the ground is associated with range safety. The flight programme is the intelligence system whose prime task is to guide the launch vehicle along an optimum trajectory and into the required orbit. This involves the following processes:

- Inertial navigation, using inputs from the inertial platform to calculate the vehicle's position and velocity.
- Guidance computation to re-optimise the remainder of the trajectory into the required orbit and to determine the current attitude of the launch vehicle.
- Control of the vehicle systems throughout the flight including stage, fairing and payload separation.

The flight programme also carries out other tasks including self-check monitoring, telemetry assembly and formatting, thrust decay monitoring, systems surveillance and fault mitigation.

After injection into orbit, the flight programme controls the satellite orientation and spin by commands to the attitude control system.

The flight programme is designed to accommodate all Ariane missions: the reference programme containing all necessary functions and mission independent data. The programme for a particular mission is produced by combining the reference programme with the appropriate flight plan and orbit data base. This process and the subsequent acceptance tests are largely automated through specially prepared support software.

Acceptance testing is carried out at the MSDS Frimley unit by running the flight programme in a real Ariane on-board computer. This is interfaced with a scientific computer con-

taining a mathematical representation of the launch vehicle's performance characteristics.

The development contract, which is worth nearly £1,000,000 to MSDS, includes in addition to the flight programme, the provision of seven vehicle equipment bay check-out programmes and one overall launcher check-out programme which is used at the launch site prior to the synchronised countdown period.

JAPAN AND ESA

Future cooperation between Japan and the European Space Agency has been under review for some time. Late last year several working groups met to discuss in detail possible areas of coordination or cooperation. The need to develop the exchange of information in the various fields of space activities was stressed.

The following areas of common interest were considered:

- *Communications:*
  It was agreed that, in view of the close similarity and interest of Japanese/European requirements for the use of satellites for telephony, data, television, maritime and aeronautical communications, a continued exchange of information would be mutually beneficial.
- *Earth Observation:*
  The parties identified as a common objective the possibility of acquiring data from remote sensing satellites of both parties.
  It has been decided that designated points of contacts will make proposals at the next meeting* in order to achieve this objective, in particular by studying the question of radio frequence compatibility, compatibility of data formats and the quality of the data products.

ESA will examine the possibility of cooperating in the use of the Japanese geodesic satellite GS-1, to be launched in 1984 after having received the relevant technical information.

- *Sciences:*
  The possibility of flying Japanese scientific instruments on European Spacelab flights was discussed. Plans for scientific satellites were also discussed and arrangements were made for exchange of more precise information on the future missions.
- *Tracking Stations:*
  Possible mutual uses of NASDA and ESA tracking stations were identified, and will be studied further.
- *Spacelab utilisation:*
  Possible cooperation and common interest in the use of Spacelab, especially in the fields of Material Sciences and Life Science together with the basic Space Sciences, were discussed and considerable interest was shown.

SPACELAB LIFE SCIENCE EXPERIMENTS

NASA has selected 78 life science areas of investigation – 74 proposals from the United States and four from three foreign nations – for two life science Spacelab/Space Shuttle flights planned between 1983 and 1985. Specific investigations will be selected for each mission about two years prior to flight.

The selected investigations include the following:

- Behaviour and Performance
- Bioengineering/Technology
- Plant Physiology
- Cellular Biology, Biophysics, Biochemistry, Immunology, Virology and Microbiology
- Developmental Biology, Embryology and Gerontology
- Endocrinology, Metabolism and Nutrition
- Musculo-skeletal and Physiology
- General Physiology and Pharmacology
- Renal, Fluid and Electrolyte Physiology
- Hematology
- Cardiopulmonary and Stress Physiology
- Cardiovascular Physiology and Clinical Medicine
- Vestibular System and Neurophysiology.

The 78 principal investigators are from US and foreign universities, private and government organizations and the NASA scientific staff. Foreign countries involved are Australia, Switzerland and the United Kingdom.

The UK contribution – the Influence of Zero Gravity on Nutation – is by Dr. D. G. Heathcote, University College of South Wales, Cardiff.

Each country is responsible for funding its own investigators.

Spacelab is a pressurized Space Shuttle system element designed to be operated by a payload specialist team of up to four persons. It is estimated that 15 to 20 investigations can be accommodated in each life science Spacelab mission.

The two missions are planned with an 18-month launch interval, the first being scheduled for mid-1983. A few additional life science investigations are expected to go on other Shuttle missions during the same time period.

MORE SHUTTLE ASTRONAUTS

The career of Astronaut, it appears, retains its attractions in the United States. A two-month NASA recruiting drive for 10 to 20 open astronaut positions for the Space Shuttle, which ended on 1 December 1979, resulted in applications from no fewer than 2,937 men and women.

More than 300 of the hopefuls applied for both mission specialist and pilot categories. The number of women applications for the two categories totalled 390.

The astronaut selection board at the NASA Johnson Space Center, Houston, will narrow the selection to those best qualified in the two categories. Approximately 100 will be selected for preliminary screening and physicals at the Center this spring.

Those selected as astronaut candidates will report to Johnson in July 1980 for their one-year training and evaluation period. Final selection as an astronaut will depend on satisfactory completion of the evaluation period.

Pay for civilian candidates will be based on the federal government's General Schedule for grades GS-11 to GS-14, with approximate salaries from $20,611 to $34,714 per year.

Military candidates will be assigned to Johnson but will remain on active military status for pay, benefits, leave and other military matters.

NASA plans to accept applications for Space Shuttle astronauts on an annual basis. The number of open positions will depend on NASA's need for pilots and mission specialists.

* *The sixth JAPAN/ESA meeting will take place in 1980 in Tokyo.*

SATELLITE DIGEST – 137

Continued from the April issue

A monthly listing of all known artificial satellites and spacecraft. A detailed explanation of the information presented can be found in the January 1979 issue, p. 41.

Compiled by Robert D. Christy

Name, designation and object number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch site launch vehicle and payload/launch origin
Soyuz-T (1) 1979-103A 11640	1979 Dec 16.520	Sphere+cone-cylinder 7000?	7.5 long? 2.2 dia	195 214 349 341 364	215 254 399 344 378	51.62 51.62 51.62 51.62 51.62	88.6 89.12 91.96 91.33 91.90	Tyuratam A-2 USSR/USSR (1)
CAT 1979-104A	1979 Dec 24.718 10 years	Cylinder 1602 (incl ballast)	1.2 dia	202	36000	17.55	633.5	Kourou Ariane ESA/ESA (2)
Horizont 3 1979-105A 11648	1979 Dec 28.44 indefinite	Cylinder+2 panels 5000?	5 long 2 dia	36290	36333	0.80	1462.9	Tyuratam D-1-E USSR/USSR (3)
Cosmos ~~1147~~ 1148 1979-106A 11649	1979 Dec 28.54	Cylinder+sphere+cylinder-cone? 6000?	6 long? 2.4 dia?	173	342	67.14	89.68	Plesetsk A-2 USSR/USSR (4)

Supplementary notes:

(1) Test flight of recoverable transport ship for use with orbiting laboratories. Soyuz-T docked with Salyut 6 about 1979 Dec 19.6. Previous tests of Soyuz-T systems were carried out by Cosmos 1001 and Cosmos 1074. Orbital data are at 1979 Dec 16.6, Dec 16.9, Dec 18.9, Dec 20.5, and Dec 25.8.

(2) First test flight of European Ariane launcher. CAT stands for "Capsule Ariane Technologique" and carries test instrumentation.

(3) USSR communications satellite intended to carry TV relays from the 1980 Olympic games in Moscow. The satellite's location is above 58° east longitude (Statsionar 5).

(4) Long life, manoeuvrable reconnaissance satellite.

Amendments and decays:

1979-100A, Cosmos 1146 was launched 1979 Dec 5.38

1979-103A, Soyuz-T (1) delete last month's entry and footnote; it has been transferred to this month's table.

Obituary—

NYMAN SIMMONS

Dr. Nyman Simmons, a former Vice-President of the British Interplanetary Society, died on 1 December 1979, aged 65. One of the pioneers of space technology in the United Kingdom, he also had a distinguished career in the science and technology of aviation.

Dr. Simmons was educated at the Central Foundation School in London, from where he won a scholarship to Queen Mary College, London. He received a First Class Honours Degree in mathematics and was awarded the Sir John Lubbock Memorial Prize for being the best mathematician of his year. After further academic distinctions, he received his Doctorate in hydro- and aerodynamics at King's College, London in 1940, where he also lectured for a time.

During World War II he served as a navigator in Wellington bombers, being the only one of his group to survive two tours of duty and was mentioned in Despatches. After leaving the RAF with the rank of Squadron Leader, he joined the Scientific Civil Service and worked on projects mainly concerned with armaments design and weapons research.

With interest in space science and technology growing in the UK, Dr. Simmons made the transition to this new field in 1963. At the time he retired in 1974 he was Assistant Director of Space 1, Procurement Executive, Ministry of Defence.

A statement issued by Dr. D. Cavanagh, Director of DSC2, MoD, includes this tribute: "Dr. Simmons stayed with the Scientific Civil Service throughout the rest of his career" (namely 1946–1974), "his work moving in a succession of reorganizations from the Ministry of Supply, through the Ministry of Aviation and the Ministry of Technology, to the Procurement Executive of the Ministry of Defence. For the eleven years before his retirement he was the Assistant Director responsible for the procurement from industry of a series of satellites to carry experiments provided by the Science Research Council, for the application of sounding rockets to various scientific investigations and to evaluation of the Earth's resources by remote sensing, and for the early stages of UK participation in European applications satellites, mainly for communications purposes. His last project with the Procurement Executive was the very successful satellite Ariel 5, launched in 1974 and still giving useful results in the field of X-Ray astronomy."

Dr. Simmons became a Member of the BIS Council in 1969 and Vice-President in 1974. His expert counsel in fields of satellite research was especially valuable to the Society in the field of remote sensing.

A UNIQUE SOCIETY PUBLICATION

HIGH ROAD TO THE MOON

Every member ought to own a copy of this unique new publication which records many of the Society's ideas and discussions on Lunar exploration in the visionary drawings and illustrations of the late R. A. Smith.

These pictures depict ideas on orbital rockets, space probes, ships to take men to the Moon and Lunar exploration. Some are familiar illustrations used in books of the time: others have not been published before.

Now Bob Parkinson – a member of the Council – has brought these pictures together with a commentary which tells how the pioneers imagined things would be – and how they were. It goes beyond the present, for man's involvement with the Moon is not yet finished. Using the Smith pictures as a background, Dr. Parkinson looks at the possible future for the Moon and how it might be brough about.

R. A. Smith, a former President of the Societ[illegible] died in 1959. He had been one of the pioneers of the [illegible]y and left behind him a collection of nearly 150 pain[illegible] and drawings which recorded one of the most visionary periods in its history.

This book is a MUST for all interested in space. For many reasons the number of copies printed will have to be limited. To avoid disappointment, later, secure your copy NOW.

Approx. 120 pp. Containing about 150 illustrations.

Large (A4) format Price £6.00 ($15.00) post free.

* * * * * *

YOUR LAST CHANCE TO OBTAIN

PROJECT DAEDALUS

Our stocks of *Project Daedalus* – the 192 pp. Report on the four-year Study by members of the Society on the requirement to send a probe to Barnard's Star – are now down to just a few hundred.

At the present rate, all copies will be sold by the end of the year. *Project Daedalus* will not be reprinted, in view of the expense involved. Members who wish to posses a copy, **must order NOW.**

Price £6.00 ($15.00) post free.

* * * * * *

INTERSTELLAR STUDIES ISSUES OF JBIS

Five 'red-cover' issues will appear in 1980, one being an enlarged, completely revised and updated "Bibliography of Interstellar Travel and Communication."

The cost of the five issues is £7.00 ($16.00). The "Bibliography" may be obtained separately at £2.00 ($5.00) post free.

A small quantity of red cover issues from 1977-79 is still available. Details can be obtained from the Executive Secretary.

BACK COPIES OF MAGAZINES

Back issues of magazines are available as follows:-

			Sterling	Dollars
(a)	*SPACEFLIGHT*			
	(i)	1977 issues – (8 only)	£ 7.00	$15.00
	(ii)	1978 issues – complete	£10.00	$22.00
	(iii)	1979 issues – complete	£10.00	$22.00
(b)	*JBIS*			
	(i)	1977 issues – (11 only)	£ 9.00	$20.00
	(ii)	1978 issues – complete	£10.00	$22.00
	(iii)	1979 issues – complete	£10.00	$22.00

Odd numbers of 1948-1960 issues of *JBIS* are also available in job lots. Details available from the Executive Secretary.

Reprint copies of most of the earlier volumes are available as follows:

(a) *SPACEFLIGHT* from Swets & Zeitlinger, Keizergracht 487, Amsterdam-C, Holland.

(b) *JBIS* from Kraus Reprint Corporation, 16 East 46th Street, New York, N.Y. 10017, USA.

(c) MICROFILM COPIES of both magazines from Xerox University Microfilm, 300 North Zeeb Road, Ann Arbor, Michigan 48106, USA.

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ALL DEPICTING OUR MOTIF

SOCIETY ITEMS

a) Cloth badges suitable for jeans, jackets, blazers, etc.

UK and Abroad £1.00 ($3.00)

b) Car Badges, (metal) for fastening on motor car grids or grilles

UK £3.00

Abroad* £3.50 ($8.00)

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d) T-shirts, in white with the Society's emblem in blue. Sizes available are Small, Medium, Large and Extra Large (42"-44")

UK £3.00

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e) Ties, dark blue

UK £3.50

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* *The reduced postage rates which formerly applied to saleable items sent abroad e.g. ties, T-shirts, etc., have now been withdrawn and replaced with rates two or three times above those for the UK. Consequently, the charges for the heavier items to be sent abroad have had to be increased to absorb these higher costs.*

Discontinued items:

The following items have been discontinued owing to difficulties in obtaining replacements at reasonable prices.

Scarves : Daedalus Blueprints : Souvenir Packs

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 27/29 South Lambeth Road, London SW8 1SZ Tel: 01-735-3160

Correspondence and manuscripts intended for publication should be addressed to the Editor, 27/29 South Lambeth Road, London SW8 1SZ.

Opinions in signed articles are those of contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Lecture
Title: **JUSTIFICATION OF SPACE PROJECT PROPOSALS**
by E. G. D. Andrews

To be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ on **23 April 1980.** 7-9 p.m.

"In the design of proposals for a major project, especially one contemplating space or interplanetary colonization, it may be necessary to take into account a wider range of constraints than can be properly organized by any single human mind unaided. The speaker has introduced a formal procedure (PADIS) based on the logic of the natural design process, which identifies the sequence in which the design investigations should be carried out to minimize reiteration, and permit effective collaboration in design to be provided by all who have relevant knowledge, without interfering with the conceptual tasks. The design of a lunar village is used for the purposes of illustration".

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Film Show
Theme: **APOLLO HEYDAY**

To be held in the Golovine Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **7 May 1980,** 7-9 p.m.

The programme will be as follows:
Doorway to Tomorrow (1967)
Spaceport USA (1970)
The World Was There (1976)
The Time of the Apollo (1975)

Admission will be by ticket only. Members should apply in good time, enclosing a reply-paid envelope. Should the number of requests for tickets exceed the accommodation available, the programme will be repeated and later participants notified accordingly.

Lecture
Title: **PLANET VENUS: 1980**
by John Bury

A lecture with a short discussion on recent experimental results and their interpretation with regard to the planet Venus to be held in the Golovine Conference Room, Society's HQ, 27/29 South Lambeth Road, London SW8 1SZ on **14 May 1980.** 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

17th European Space Symposium
Theme: **ASTRONAUTICS IN THE 1980s AND BEYOND**

A three-day meeting to be held at the Royal Commonwealth Society, London W.C.2 from 4-6 June 1980, sponsored by the BIS, AAAS, AIDAA and DGLR and co-sponsored by EUROSPACE.

Offers of papers are invited. Please contact the Executive Secretary for further information. Registration is necessary. Copies of the programme will be available in due course.

Symposium
Title: **SPACE TRANSPORTATION**

To be held in the Society's Golovine Conference Room at 27/29 South Lambeth Road, London SW18 1SZ on 11 June 1980, 9.30 a.m. to 4.30 p.m.

Registration is necessary. For further details and application forms apply to the Executive Secretary at the above address.

Visit
SRC APPLETON LABORATORY

Arrangements have been made for a small party of members to visit the SRC Appleton Laboratory at Ditton Park, Slough, together with a visit to their out-station, the Satellite Signal Reception Centre at Winkfield, on **10 September 1980** (all day).

Registration is necessary. Members interested in receiving further information must apply to the Executive Secretary, enclosing a reply-paid envelope, in good time.

35th ANNUAL GENERAL MEETING

The 35th Annual General Meeting of the Society will be held in the Tudor Room, Caxton Hall, Caxton Street, London S.W.1 on **18 September 1980,** 7.00 p.m.

A detailed Agenda will appear in *Spaceflight* in due course.

Nominations are invited for election to the Council. Forms can be obtained from the Executive Secretary. These should be completed and returned not later than 25 June 1980.

Should the number of Nominations exceed the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members.

31st IAF CONGRESS

The 31st Congress of the International Astronautical Federation will be held in the Takanawa Prince Hotel, Takanawa, Minato-ku, Tokyo, Japan from **21–28 September 1980.**

Members of the Society intending to present papers are asked to notify Dr. L. R. Shepherd, Chairman of the BIS International Liaison Committee at Society H.Q. as soon as practicable.

Lecture
Title: **SPACE REVIEW – 1980**
by P. S. Clark

A review of space activities throughout the world which have taken place during the past twelve months, to be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ, on **8 October 1980,** 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Film Show
Theme: **HISTORY OF ASTRONAUTICS**

A number of early films on astronautics not now generally available will be screened at a meeting to be held in the Golovine Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **5 November 1980,** 7-10 p.m.

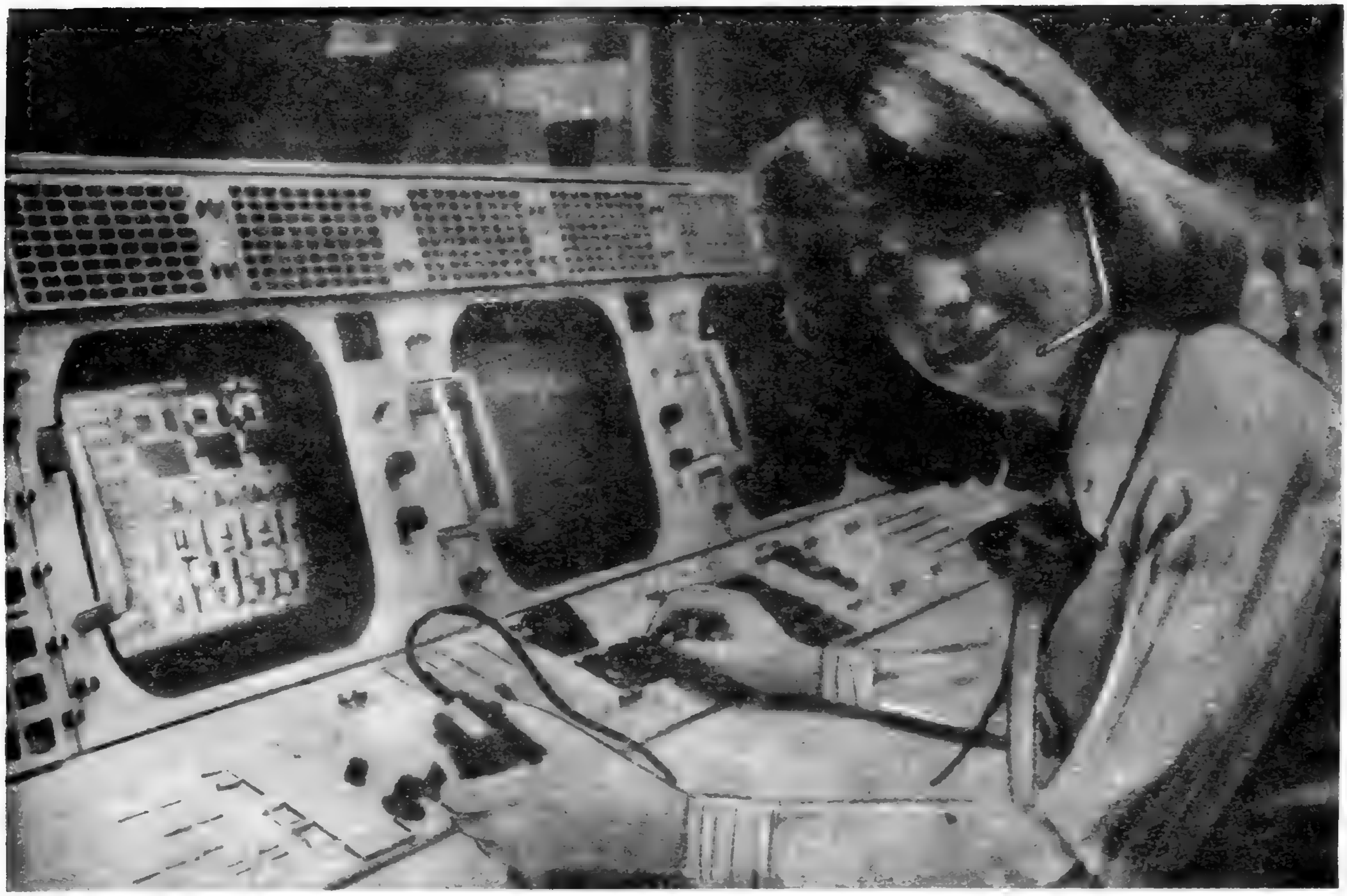
The programme will include the following:
(a)—History of Rocket Development
(b)-Black Knight

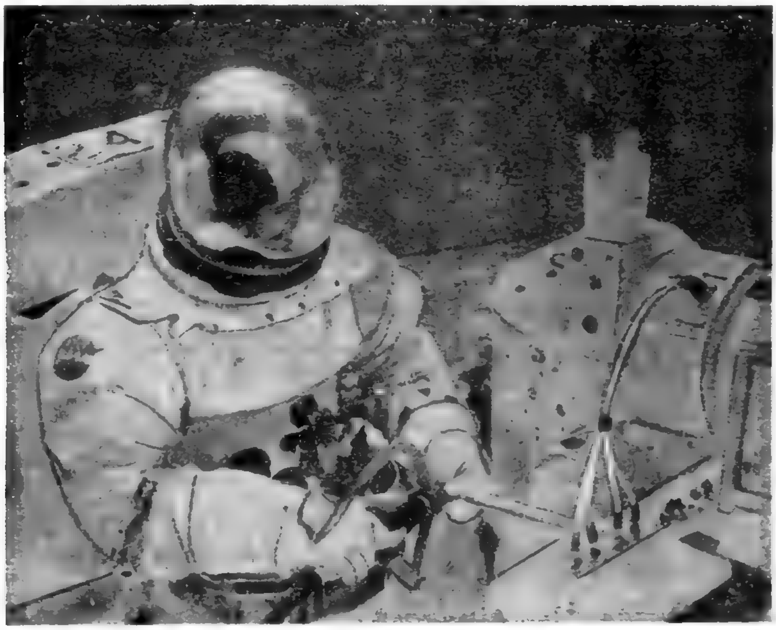
Admission will be ticket only. Members should apply in good time, enclosing a reply-paid envelope.

Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published for The British Interplanetary Society Ltd., (No. 402498) by Space Educational Aids Ltd., (No. 741211). Registered Office, 27/29 South Lambeth Road, London, SW8 1SZ, England.

ISSN 0038-6340

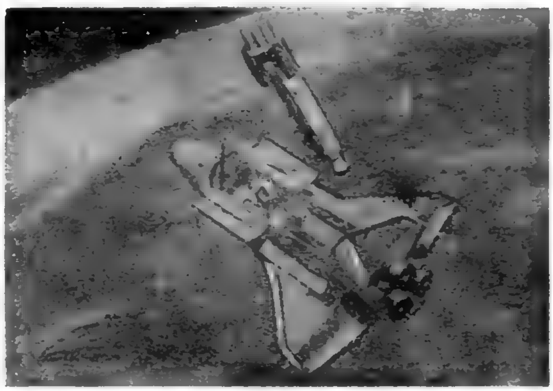
SPACEFLIGHT





VOLUME 22 NO. 6 JUNE 1980

Published by
The British Interplanetary Society



SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 No. 6 JUNE 1980 *Published 15 May 1980*

Editor:
Kenneth W. Gatland, FRAS, FBIS

CONTENTS

COVER

SPACE WOMEN. Women are now taking their place alongside male counterparts in the US space programme. *Top,* Jackie Parker, 19, at the console she will use during Space Shuttle missions, is the youngest flight controller in the history of manned space flight. She will work in support of Data Processing Systems during ascent phases of Shuttle flight – from launch through the first few hours of orbital missions. *Bottom left,* Dr. Shannon Lucid, one of America's prospective Mission Specialists, trains for spacewalk activity in the Neutral Buoyancy Simulator – a 1,300,000 gallon water tank – at the Marshall Space Flight Center. She is practicing to use a power tool during simulated servicing of a Space Telescope. *Right,* Space Shuttle Orbiter discharging satellites in orbit.

NASA and Rockwell International

A Place for Europe?

A major user of space technology, the International Communications Satellite Consortium, appears to have more confidence in ESA's Ariane booster than the trouble-plagued Space Shuttle, writes Gordon L. Harris.

J. L. McLucas, executive vice president of COMSAT, the American agency which manages INTELSAT for 102 member nations, prefers Ariane "because it is based on proven technology. It is not pressing the state of the art like Shuttle."

Two more INTELSAT spacecraft will be launched in September and December, 1980 on Atlas Centaur boosters. Three others were committed to Shuttle flights but INTELSAT has transferred one of them to Ariane. McLucas indicated that future spacecraft will be compatible with either Shuttle or Ariane.

"We will not start designing for Shuttle only until the vehicle has proven itself," he said. Like other INTELSAT officials, McLucas declared he is disappointed in Shuttle progress. "It has made the United States look disorganized, it's very unfortunate," he added.

While the Shuttle's greater payload capacity will recommend it, European members of INTELSAT who comprise 25 percent of the member states are pressuring the organization to rely on Ariane. "They want assurance that Ariane is in the programme," McLucas explained.

Meanwhile NASA Administrator Robert Frosch, trying to restore confidence in the Shuttle system, asserted there will be more than enough launch activity for the U.S. and European vehicles.

MILESTONES

February 1980

22 Aeritalia and SNIA Space and Defence Division announce an agreement with the Italian board of national research to "develop and produce a new space vehicle suitable for inter-orbital space transportation." Called IRIS (Italian Research Interim Stage) the propulsive stage is designed to transfer from low orbit into transfer orbit, any kind of geostationary satellite for meteorological observation, telecommunications, and monitoring of Earth resources and atmospheric pollution. It can be operated from the Space Shuttle or the European Ariane.

28 NASA announces that after 16 years of developing and flying spacecraft to various planets and into orbit around the Sun, the Pioneer Project Office at Ames Research Center is closing down. Responsibility for operation of the seven Pioneers still working in interplanetary space is being transferred to the Space Missions branch at Ames. Spacecraft still operating are: the four Pioneers 6 to 9, which currently form a network of solar weather stations around the Sun, and Pioneer 10 and Pioneer 11, both headed out of the Solar System after the first two flights to Jupiter and the first flight to Saturn. Pioneer Venus continues to orbit the cloud-shrouded planet photographing cloud circulation, mapping Venus' surface, and taking a range of other data.

28 INTELSAT announces that overseas demand for satellite telecasts of the Winter Olympics almost doubled during the Games. When the 1980 Games opened at Lake Placid, New York, INTELSAT was holding bookings for 260 hours of international satellite television for the Games, but a tally of usage after the Games showed that a total of 448 hours had been used.

March 1980

4 Scottish Office announces that HM The Queen has been pleased to appoint Dr. Malcolm Sim Longair as Astronomer Royal for Scotland and Regius Professor of Astronomy in the University of Edinburgh. The appointment takes effect on 1 October 1980 when he will replace Professor V. Reddish, whose resignation was announced last year.

Continued overleaf

В журнале не печатается ряд страниц.

4 NASA announces that a plan to increase the cargo-carrying capacity of the Space Shuttle for near-polar orbit missions from Vandenberg AFB is underway at the Marshall Space Flight Center, Huntsville, Alabama. Contracts for programme definition studies of a liquid propellant boost module to be attached to the Shuttle's External Tank have been awarded to Martin Marietta Corporation and Aerojet Liquid Rocket Co. "These studies will involve adaptation of portions of the Air Force Titan launch vehicle to the Space Shuttle to provide additional boost for launch." The liquid boost module is expected to increase the Shuttle's payload capability from 24,000 to 36,000 lb (10 886 to 16 324 kg).

6 Science Programme Committee of European Space Agency decides to include a new scientific project, an astrometry satellite 'Hipparcos', to measure the astrometric parameters of celestial bodies (positions, proper motions and parallaxes). With the satellite it should be possible to determine "with very high accuracy the position and displacement velocity of about 100,000 stars." *Hipparcos:* Mass (without apogee motor) 376 kg, including a payload of 117 kg; will be of a very advanced design. It is expected to be launched by the ESA Ariane into a geostationary orbit in mid-1986. Total estimated cost 139.3 MAU.

10 Second group of 20 astronaut applicants report to Johnson Space Center for a week of physical exams and interviews. All in the second group are mission specialist applicants from among the 3122 men and women who applied last autumn. There are five women in the group.

11 Reported that President Carter has elected not to seek ratification by the Senate of the United Nations 'Moon Treaty' this year. Decision followed successful lobbying by L-5 Society and others interested in keeping open the options for the commercial development of lunar resources, e.g. O'Neill Space Colonies and related industrial products. One argument—taken up by the Senate Foreign Relations Committee—was that adherence to the Treaty would "create a system of international socialism by foreclosing the commerial uses of outer space to American free enterprise."

13 First full power level test (at 109 percent of rated power level) of the Space Shuttle Main Engine is successfully conducted at NASA's National Space Technology Laboratories in Mississippi. Regarded as "a significant milestone in the development of the engine for full power level abort capability." Total test time was 125 sec with 10 sec at full power level and a total of 26 sec above 100 per cent rated power level.

13 Mr. William Whitelaw, UK Home Secretary, announces that a study is to be made of a direct broadcasting satellite service which could give the UK five extra TV channels by 1985-1990. Although there were no plans for such broadcasts at present, he said, "I believe that it is important to keep the possibilities offered by technical developments in broadcasting under review."

14 NASA announces that a major new NASA flight simulation facility, called the Vertical Motion Simulator, at Ames Research Center, will be used to help evaluate changes planned for the Shuttle orbiter control system. Primary objectives of the Shuttle modifications "is to improve the control characteristics of the spacecraft in the atmospheric re-entry phase and during landing and rollout."

BRAZIL IN SPACE

By Theo Pirard

Because its industrial resources cover half the territory of South America, Brazil is looking to space technology to meet the social and economic requirements of its development. It appears that Brazil is seriously interested in making an independent contribution to space research and applications. It needs to challenge these techniques in preparation for the next century.

Introduction

Brazilian space activities started with the creation, in the 1960s, of two separate institutes:

- INPE, or Institute for Space Research, as part of the National Council for the Development of Science and Technology, is the main agency for civilian space research.
- IAE, or Institute for Space Activities, depending on the Ministry of Aeronautics and on its Centro Technico Aeroespacial (CTA) is concerned with the development of Brazilian rocketry.

The INPE and IAE have their respective headquarters located side-by-side at Sao José dos Campos (State of Sao Paulo). In some fields of space applications, the two institutes have redundant activities, due to their specific characters: INPE is civilian and IAE is managed by military authorities. Both institutes are particularly interested in remote sensing observations.

A spectacular view of CLFBI on the Brazilian coast during the launching of a Sonda II-A rocket on 13 December 1978.

Photo: IAE

The Technology of Spacecraft

Hopefully, the first Brazilian satellites will be launched in the early 1980s. Since 1971, INPE has been studying the use of spacecraft technology in astrophysics, remote sensing, ionosphere, meteorology and geodesy studies. Total staff of INPE numbers between 750 and 1000, approximately ⅓ of whom are graduates. Major facilities are established at Sao José dos Campos (headquarters) and in Cachoeira Paulista (balloon launching centre); other installations are at Cuiaba (Landsat receiving station), at Natal (rocket launching facility) and at Fortaleza (satellite tracking centre).

INPE is regularly launching stratospheric balloons equipped with highly efficient telescopes which are realized in cooperation with some European nations (France, Italy, Belgium) and with the United States. With "Sonda" rockets and with NASA satellites, precise measurements have been made of certain ionospheric effects in South America.

In meteorological observations, INPE has a very active role in the collection of useful data concerning the Southern Hemisphere: it investigates the atmosphere with sounding rockets and operates a network of stations for the reception and processing of signals from near-polar orbit NOAA satellites and from the geostationary GOES and Meteosat.

INPE finds two space applications particularly interesting for developing the very large territory of Brazil (8.5 millions of km^2). These are remote sensing of Earth resources using Landsat imagery, and communications satellites for economic and educational purposes. INPE is testing a Bandeirante aeroplane equipped with several sensors in order to improve the interpretation of Landsat data. The most significant programme for Brazil is the Crop Survey: with the former configuration of INPE's Image-100 system (developed by General Electric), very good results have been obtained from surveys of areas of approximately 36,000 km^2. The short term objective is to have a crop survey system for sugar cane covering the entire State of Sao Paulo, which is one of the most important in terms of agriculture.

While the remote sensing activities of INPE are growing with the financial support of the Brazilian Government, the domestic comsat project has suffered delays because of the large investment needed. In the 70s, INPE tried to promote the SACI (Satelite Avançado de Communicaçoes Interdisciplinares) Project, and useful studies and interesting experiments have been made for the application of space technology in rural education [1].

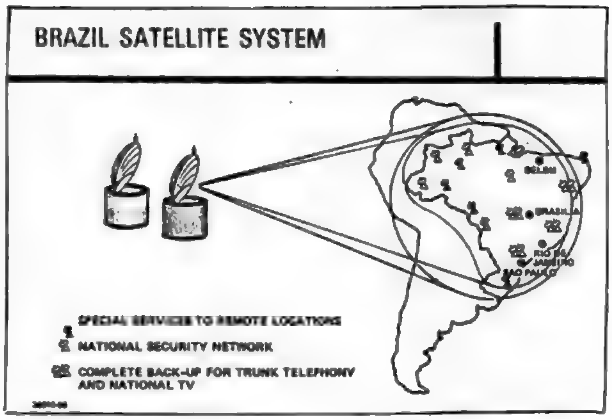
An objective of the coming years is the development of satellite hardware in Brazil. INPE is organizing a Satellite Technology Programme for the definition of the first Brazilian spacecraft: this will be a scientific satellite which must be put into a low Earth orbit by a national launch vehicle [2].

Concerning preparations for the domestic comsat project, the Brazilian industry is interested in supplying a large proportion of the required materials and equipment. In fact, Brazil would expect to take up the domestic satellite system by 1982 or 1983. According to the Minister of Communications, "the putting into orbit of a domestic satellite by Brazil can be considered from two different points of view: on the one hand, the satellite could contribute effectively to the rationalization of the occupation of Amazonia and the establishment of man in the interior of the country, through the supply of public telecommunications services, including television, which today attracts thousands of migrants to the cities. On the other hand, the geosynchronous orbit occupied by the communications satellites is limited, like a kind of nonrenewable resource. It is thus essential that Brazil should occupy its place with relative urgency". There would be technical and economic advantages in integrating the present Earth-based microwave system with

Left, map of the Brazilian communications network including both satellite and microwave links.

communications via satellite in a country the size of Brazil, large areas of which still lack the means of transportation and even with low population density, as is the case in Amazonia and the West Central region [3].

During the past ten years, the Embratel company expanded and modernized the telecommunications system, changing the Brazilian "archipelago" into a real continent. Embratel transformed Brazil by installing more than 20,000 km of microwave routes, a network of coastal stations, communication via satellite, two undersea cables between Brazil and Europe and Brazil-USA. Actually, Brazil is using Intelsat 4A with 10 Earth stations; it has an important centre, with three antennae, at Tangua, near Rio de Janeiro [4].



Towards a Satellite Launcher

Brazilian authorities and industries are studying plans to make their country capable of launching satellites; Brazil expects to follow India as a "space power". The development of the national launch vehicle, based on the technology of the present "Sonda" rockets, is the principal task of the IAE engineers and technicians. Currently, IAE is working on solid boosters for sounding rockets and missiles. Its modern launch complex is located on the north-eastern coast of Brazil, near the great city of Natal: it is the Rocket Launch Site at the Barrier of Hell or Campo de Lançamento de Foguetes da Barreira do Inferno (CLFBI). From the CLFBI range, three models of Sonda rockets are currently fired for technological and scientific purposes some of them with cooperative payloads. The family of the Sonda solid rockets includes several variants:

- Sonda I is a small two-stage rocket (3.1 m or 10 ft) long able to launch 5 kg (11 lb) up to altitudes of 100 km (62 miles) for meteorological observations; more than 200 Sonda I have been used together with a number of foreign rockets.
- Sonda II has three different versions and is a single-stage rocket. Sonda II-A and Sonda II-C are operational and regularly launched in order to conduct experiments up to 120 km (70 miles) altitude. Sonda II-B is the most powerful and can launch payloads of 50 kg (110 lb) to an altitude of more than 200 km (125 miles).
- Sonda III is another two-stage solid rocket which uses as 2nd stage the Sonda II-A. Launched since February 1976, it can carry 60 kg (130 lb) up to high altitudes (600 km or 380 miles)!

For the 1980s, IAE is preparing more powerful boosters in order to develop a Brazilian launch vehicle for small satellites.

MAGNETIC SATELLITE

The United States has launched a new Earth satellite that may be able to tell scientists more about the movements of the Earth's crust and the location of important mineral deposits in the crust, writes USICA Science Correspondent, Everly Driscoll.

The polar-orbiting spacecraft, known as "MAGSAT" (for the Magnetic Field Satellite), is designed to measure the Earth's near-surface magnetic fields and, indirectly, crustal features related to earthquakes and mineral deposits.

During its 120-day life span, Magsat will measure the strength and trace the direction of both the Earth's global magnetic field and its "surface" magnetic fields.

Magnetic fields are caused by electric currents that flow through and around Earth and through the upper atmosphere. The "surface" fields can be induced by magnetic storms, or can be caused by certain elements in the Earth's crust. One large magnetic surface anomaly, for instance, is an iron deposit in the middle of Africa, detected by a satellite magnetometer.

"From the Magsat data, we will produce world-wide magnetic charts for navigation, global magnetic field models and maps of Earth's surface showing the location of the magnetic irregularities such as the one in Africa," said Pitt Thome, NASA's Director of resource observations.

After locating the surface magnetic irregularities in the Earth's crust, scientists will have a better understanding of the evolution of the crust and the various geologic processes that led to the formation of ore and petroleum deposits, said Dr. John Denoyer, a research geophysicist at the Department of Interior's US Geological Survey (USGS). The USGS will produce the magnetic maps.

Scientists have known for some years, of course, that electric currents are involved with magnetic fields, and that rock formations – layers of Earth's crust – of certain composition conduct electricity better than rocks of other composition. From magnetic data, thus scientists can deduce the temperature, composition and structure (such as faults) of rock formations. Of particular interest are those formations known to be characteristic of petroleum and mineral deposits.

What scientists did not know was that this could be done, in part, with a satellite. The indirect method of probing the geology and composition of the crust was discovered accidently between 1965 and 1971 when US scientists were analyzing data from six US satellites carrying magnetometers. Those magnetometers were designed to gauge the strength of the global field originating in Earth's core and shed some light on how that field formed and why, over millions of years, the field reverses itself – that is, the Magnetic North becomes Magnetic South.

"In the process of studying these data, we discovered that the data obtained by the satellites when they were at lower altitudes contained separate magnetic fields due to irregularities in the Earth's crust," Thome explained.

"This opened the door to a new class of investigations" – using magnetic measurements to deduce the physical characteristics of rocks and how their differences relate to mineral and oil deposits," he added.

"The magnetic measurements when combined with geophysical data such as gravity will help in the location of mineral and petroleum deposits of economic importance," said Dr. Denoyer.

Magnetic maps of Earth's surface are also important clues to the movement of the continents. Certain magnetic features of Africa, for example, look the same as those in South America, indicating that the two continents were once probably connected. Earth's surface is now comprised of a dozen or so "plates" that are constantly moving about. Some plates are coincident with continents. This movement in turn triggers earthquakes.

"By watching how the magnetic fields vary with time, we hope to shed some light on how the plates of Earth move with time," said Thome.

Because Magsat is in a low-earth orbit – 350 by 500 kilometres – the "surface" magnetic fields will be detailed with five times the resolution of that obtained from other magnetometers flown at higher altitudes. In addition, Magsat will measure the direction of the magnetic fields as well as their strength.

Scientists on every continent will be comparing data measured on the surface with the satellite data. In fact, more than a third, 13, of the 32 scientists who will be interpreting Magsat data over the next two years, are from other countries – Australia, Brazil, Canada, France, India, Italy, Japan and the United Kingdom.

CONFERENCE ON SPACE MANUFACTURING

The 1979 Princeton Conference on Space Manufacturing, co-sponsored by the Space Studies Institute, the American Institute of Aeronautics and Astronautics and the US Department of Energy (DoE), reported the following:

(1) That so far "no unacceptable effects" have been discovered in research into the environmental impact of SPS and its microwave transmission system (interim conclusions by DoE officials).

(2) Experimental data on the direct electrolysis of lunar glasses and on the formation of spun glass and clear glass from lunar minerals.

(3) The conclusion that a chemical processing plant to separate lunar minerals into pure elements can best be developed using terrestrial wet-chemistry methods, and that such a plant should process 80 times its own mass per year.

(4) Student research results that (a) a mass-driver reaction engine need not have a rigid structure, but can be straightened by lateral magnetic forces derived from the moving buckets, under active feedback, and (b) flying-spot scan experimental data that a mass-driver payload leaving the lunar surface can be measured to a precision of 0.4 mm or better, corresponding to a worst-case error of 0.6 metres × 10 metres at the collection point.

The mass-driver bucket cooling station (liquid helium temperature) was completed at M.I.T. and brought to Princeton for display at the Conference. The accelerator section (1.25 metres) was assembled at Princeton at the end of June. The recharging supply and many auxiliary circuits are also complete. First dynamic tests will be made with a non-cryogenic (i.e. ohmic) bucket running in air. Power tests are beginning cautiously for safety reasons – "the accelerator draws its energy from a charged capacitor-bank so husky that it can supply four million watts."

The two other High Frontier research areas now most active at Princeton are orbital mechanics and scaling. Scott Dunbar is continuing his work on the orbital mechanics of Earth-Trojan asteroids. Studies of minimum-cost approaches to high productivity in space are in progress, using the methods of scaling and bootstrapping. This work will be continued using the latest data available; "it appears a high-payoff programme is reachable well within Shuttle lift contraints, possibly at a total programme cost no more than that of Shuttle development."

The Space Studies Institute's highest "New Start" priority is to sponsor a bench-chemistry research project to develop a working model for converting lunar soils to pure elements. A request for research proposals will be made by the Institute only when adequate funds for the project have been accumulated.

TWO-COMET MISSION

NASA, in cooperation with the European Space Agency, is asking scientists to propose experiments for a planned international mission to two comets – Halley and Tempel 2. The total journey will span four years and cover more than 2,500 million kilometres (1,600 million miles).

Utilizing solar electric propulsion engines for the first time in deep space, the spacecraft will fly past Halley's Comet in 1985, release an instrumented probe toward the comet and then go on to encounter Tempel 2 in 1988 and fly side by side with it for a year or more as Temple 2 swings round the Sun.

Closeup pictures and other scientific information returned by the spacecraft are expected to add significantly to our knowledge about comets, which in turn may shed more light on the origin and evolution of the Solar System.

NASA emphasized that the project has not yet been approved but that early selection of scientific participants and investigations is required for a prompt start if approval is granted.

Under current plans, NASA will be responsible for the launching, rendezvous spacecraft system and mission operations. The European Space Agency* will be responsible for the Halley probe system. The combined scientific payload will be shared by scientists throughout the world.

The proposed mission has three major science objectives:

- *To determine the chemical and physical nature of the comet's nuclei.*
- *To characterize the chemical and physical nature of the comas, the gases and dust which surround the nuclei when the comets approach the Sun; and*
- *To determine the nature of the comets' tails.*

Instruments on the Halley probe and the rendezvous spacecraft will sense the comets remotely as well as collect dust and gases for onboard analysis.

Comets are relatively small bodies circling the Sun in orbits of widely different periods and distances. They are believed to be composed of loose mixtures of water ice, frozen methane, ammonia, carbon dioxide and other gases, with bits of cosmic dust, rock and sand. The combined nucleus and coma make up the head of the comet, which may grow from 2,000 to 200,000 km (1,500 to 150,000 miles) or more across as it approaches the Sun.

Comets grow tails of dust and gases as they are heated when they get close to the Sun. The tails range from millions to hundreds of millions of miles in length.

The opportunity to make close visits to two different types of comets is ideal for the scientists who are trying to understand these "mavericks of the Solar System." Because comets spend most of their time far from the Sun their original material is believed to be preserved as if it were in a deep freeze. By sampling this material, scientists hope to unlock some of the secrets surrounding the formation of the Solar System.

Since comets can be quite different in their chemical and physical characteristics, it is important to sample more than one type. Among large highly active comets which display the full range of phenomena, only Halley has a predictable orbit. It will make its once-every-76-years appearance during the winter of 1985-86. Accordingly, the mission contemplates a flyby of this comet which will not be seen again until 2061.

Unlike Halley, Tempel 2 is smaller and relatively stable. It is typical of a class of comets known as short-period comets which are easier to visit by a spacecraft but exhibit less active phenomena.

The Halley/Tempel 2 comet mission will be launched by a Space Shuttle in July 1985. The spacecraft will be propelled in deep space by ion (solar electric) propulsion, a new fuel-efficient technology system now under development by NASA.

The spacecraft will encounter Comet Halley in November 1985, about 120 million km (75 million miles) from Earth, and eject a probe that will plunge into the coma, returning a variety of data. At that time, Comet Halley will be travelling relative to the spacecraft at a speed of 57 km/sec (127,000 mph).

The probe will pass within 1,500 km (930 miles) of the nucleus. Data acquired by the probe will be transmitted to Earth via the spacecraft. The spacecraft will then pass 130,000 km (81,000 miles) on the sunward side of the nucleus, and head for Tempel 2.

At Tempel 2 rendezvous, the spacecraft will approach the comet at a distance of a few thousand kilometres, well outside the theoretical "dust hazard" envelope, and assess the hazards. If all looks well, controllers will command the spacecraft to proceed to within 100 km (60 miles) and finally to within 50 km (30 miles) of the nucleus. The spacecraft will stay with Tempel 2 for a year or more, obtaining high-resolution pictures and other measurements of the nucleus and other cometary parts. The onboard cameras may ultimately be able to detect objects as small as a baseball on the surface of the nucleus.

The Jet Propulsion Laboratory, Pasadena, California, will manage the mission for NASA's Office of Space Science, Washington, D.C. The laboratory, a government-owned facility operated for NASA by the California Institute of Technology, also will be responsible for a rendezvous spacecraft system and mission operation. A European Space Agency project team will be responsible foi the Halley probe.

The design, development and implementation of the mission will involve the direct interaction of NASA and the European project teams and a Project Science Group composed of principal investigators, team leaders and selected interdisciplinary scientists.

* *European Space Agency states are Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom.*

PIONEER SATURN RESULTS

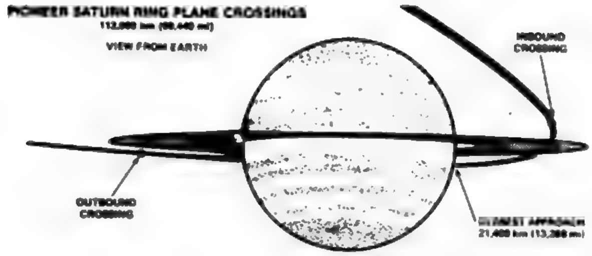
NASA's Pioneer 11 spacecraft continues to work well after successfully flying past Saturn, the most distant planet yet reached in space exploration. The tiny space robot is now heading out of the Solar System after returning the first closeup pictures of Saturn and making a number of important scientific findings, including the discovery of two new outer rings and possibly a new Saturnian moon. In addition, Pioneer sustained no damage from high-velocity ring particles showing that spacecraft can operate safely in the vicinity of the visible rings.

After a six-year trip of more than 3,200 million kilometres (2,000 million miles) in space, Pioneer spent 10 days photographing and measuring the ringed planet. As it made its closest approach on 1 September to within 20,800 km (13,000 miles) of Saturn's cloud tops at a speed of 114,500 km/hr (71,200 mph) some 1,600 million km (1,000 milliom miles) from Earth, Saturn's gravity swung it almost 90 degrees on a change of course towards the edge of the Solar System.

Without a failure, Pioneer can return useful data until the late 1980s, when it reaches the limit of its radio contact with Earth.

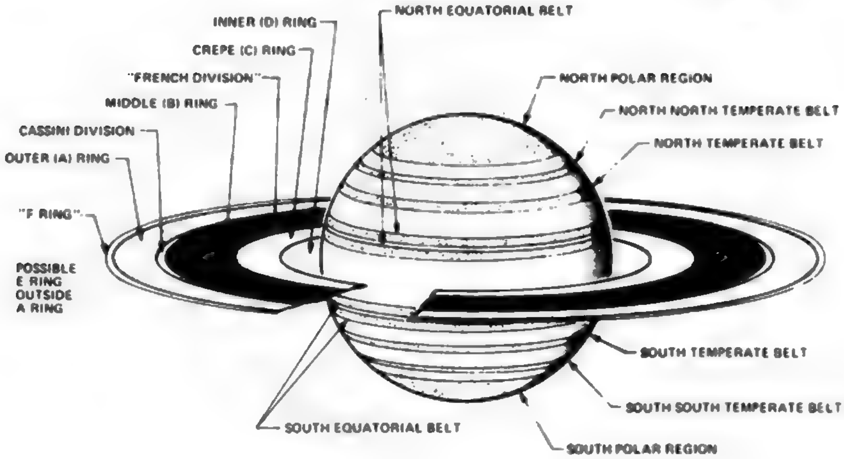
Major findings about Saturn are summarised below:

- Saturn has an 11th moon. It was discovered in a photo taken of the outer edge of Saturn's rings and by instrumentation on board the spacecraft. Its estimated diameter is 400 km (250 miles). The new moon has been named 1979S1.
- Saturn has a magnetic field, magnetosphere and radiation belts. It joins Earth and Jupiter as a magnetic planet.
- Because of the low temperature measurements, evidence for the possibility of life on the planet's satellite Titan was discouraging, but not eliminated.



NASA/Ames Research Center

The planet Saturn.



	km	mi
SATURN DIAMETER	119,000	74,000
FROM SATURN TO –		
C RING	12,570	7,810
B RING	31,730	19,720
CASSINI DIVISION	56,870	35,340
A RING	61,660	38,320
OUTER EDGE OF A RING	77,250	48,000
F RING	80,470	50,000

- Two new rings have been identified. One, which has been called the F ring, is separated from the A ring by a 3,600 km (2,240 miles) gap, called the Pioneer division. The F ring was clearly visible in a closeup picture taken some 943,000 km (586,000 miles) away from the planet. A second ring, the G ring, also was discovered and lies between the orbits of the satellites Rhea and Titan or about 500,000 km (312,500 miles) from the cloud tops.
- A feature called the French Division, a division between the middle and inner visible rings (B and C rings), was seen in Pioneer pictures of the shadow of the rings on Saturn's surface. It was named after French astronomers who first suggested its presence.
- Substantial particle material was seen in Cassini's Division and in the outer and inner portions of the A ring. The Cassini Division looks empty when viewed from Earth, i.e., from the sunlit side of the rings.
- The B ring was found to be so opaque that it allowed almost no light to pass through it.
- The C ring was found to have few particles and appeared as diffuse as Cassini's Division.
- Pioneer found no evidence of either an innermost D ring or the expected outer E ring.
- Preliminary measurements of the ring mass indicate they have a low density. This suggests they are made up largely of ice.
- A substantial glow of atomic hydrogen was found around the rings which suggests absorption of protons from the radiation belts caused dissociation of water ice in the rings.
- Pioneer sustained two meteoroid hits above the rings and three more hits below the rings.
- Gravity field measurements indicate that Saturn is flattened about 10 per cent at the poles by its rapid rotation and is not an oval body. It has a depression at mid-latitudes of about 120 km (99 miles).
- Gravity field analysis and temperature profile measurements suggest that the planet's core, extending out about 13, 800 km (8,575 miles) from the centre, is about twice the size of the Earth, but is so compressed by Saturn's huge mass that it contains about 11 Earth masses of material, largely iron and rock.
- Above the core, out about another 21,000 km (13,125 miles), the measurements suggest that the planet consists of liquid metallic hydrogen, which does not exist on Earth. The presence of liquid metallic hydrogen is supported by the discovery that the planet has a magnetic field. To produce this field, a planet needs fast rotation and a liquid electrical conductor in its interior – in Saturn's case, liquid metallic hydrogen.
- Two and half times more heat is radiated into space by Saturn than is absorbed from the Sun. One interpretation of this observation is that perhaps only a third of Saturn's heat is generated by leftover heat of planet formation and by continuing gravitational contraction, with the most heat being generated by denser helium sinking through the planet's liquid hydrogen interior. The upper atmosphere was determined to be 5 C (41 F.) warmer than expected.
- Saturn's magnetic field is 1,000 times stronger than Earth's and 20 times weaker than Jupiter's. The field is unique because its north-south axis lines up with Saturn's rotation axis, unlike the 10 degree tilt to the rotation axis of Earth, Jupiter and the Sun.
- Saturn has a magnetosphere, a magnetic "bubble" in the solar wind which surrounds Saturn, which is larger than Earth's, but smaller than Jupiter's. The nose of the tear-drop-shaped magnetic envelope is usually about 1,250,000 km (775,000 miles) from the planet. Its width is about 3,400,000 km (2,100,000 miles).
- The planet has radiation belts made up of high energy electrons and protons which are comparable in intensity to those of the Earth, although the region they occupy is about 10 times larger. They are several hundred times weaker than Jupiter's.
- The radiation belts are completely eliminated by Saturn's rings because their high energy particles mirror back and forth between Saturn's poles about once a second, finally striking ring material which absorbs them. This is the most radiation-free sector of space yet found in the Solar System.
- The moons *Janus, Enceladus* and *Tethys* also absorb large numbers of radiation belt particles.
- Closeup pictures showed Saturn's cloud tops, unlike Jupiter's, have few details.

- Saturn's cloud tops appear to be lower at the poles than at the equator. As a result polar clouds were seen ranging from dark blue to slightly green and changing to brownish belts around 55 degrees latitude.
- There appear to be jet streams around 70 degrees latitude and overall the planet appears to have more and narrower belts and zones than Jupiter.
- Infrared instrumentation showed the equatorial zone cooler than adjoining higher latitude regions and clouds of this zone are, therefore, probably higher. This suggests height and temperature differences between the belts and zones as expected.
- Ultraviolet instrumentation may have detected a generalized hydrogen glow or the presence of auroras on Saturn.
- Titan was found to have a cloud top temperature of −198 C (−324 F.). This very cold temperature eliminates an internal heat source as a means of warming Titan's surface, but leaves the possibility of atmospheric heating from a greenhouse effect.
- Light from Titan was found to be strongly polarized which is expected to allow determination of the kinds of aerosols or particles believed to be in the satellite's atmosphere.
- The ultraviolet instrument found a hydrogen cloud around Titan. This suggests its methane atmosphere is slowly breaking down into hydrogen and carbon, with the hydrogen escaping into space and carbon-based aerosols falling to the surface.
- Pioneer measurements are providing an improved mass and diameter for Titan. These measurements are expected to provide a density determination and estimates of its interior. Its density is believed to be low enough for it to contain significant quantities of interior ice.
- Titan has a magnetic wake within Saturn's magnetosphere. It extends ahead of the satellite instead of behind it, because of the planet's fast magnetosphere rotation.

The Pioneer programme is directed by the Office of Space Science, NASA Headquarters, Washington, D.C. Project management is the responsibility of NASA's Ames Research Center, Mountain View, California. The spacecraft was built by TRW Systems, Redondo Beach, California.

JUPITER'S 'NEW' MOON

A new moon of Jupiter has been discovered in pictures taken by NASA's Voyager 2 spacecraft on 8 July during the excursion through the Jovian system.

While studying pictures of Jupiter's thin ring of particles taken by Voyager 2 cameras less than 24 hours prior to the spacecraft's close encounter with the planet, two researchers at the California Institute of Technology – graduate student David Jewitt and scientist G. Edward Danielson, a member of the Voyager Imaging Science team – determined that a star-like object in the ring plane was a moon.

Temporarily designated 1979J1, the new satellite is the 14th known to be circling the giant planet. (Another possible moon, farther out from Jupiter and awaiting confirmation, may have been seen in photographs obtained from Earth several years ago by Charles T. Kowal of Caltech, discoverer of Jupiter's 13th satellite).

The new moon adds to the list of newly-found Jovian phenomena first observed by Voyager 1 in March 1979 and expanded upon by Voyager 2 four months later. Among these firsts are the ring itself, extensive volcanic activity on the satellite Io, and tremendous bolts of lightning in Jupiter's atmosphere.

1979J1 is the closest moon to Jupiter, orbiting the planet at the outer edge of the ring about 57,800 km (36,000 miles) from the cloud tops. It is estimated to be only 30 to 40 km (18 to 25 miles) in diameter, smaller than seven of Jupiter's other moons but larger than six.

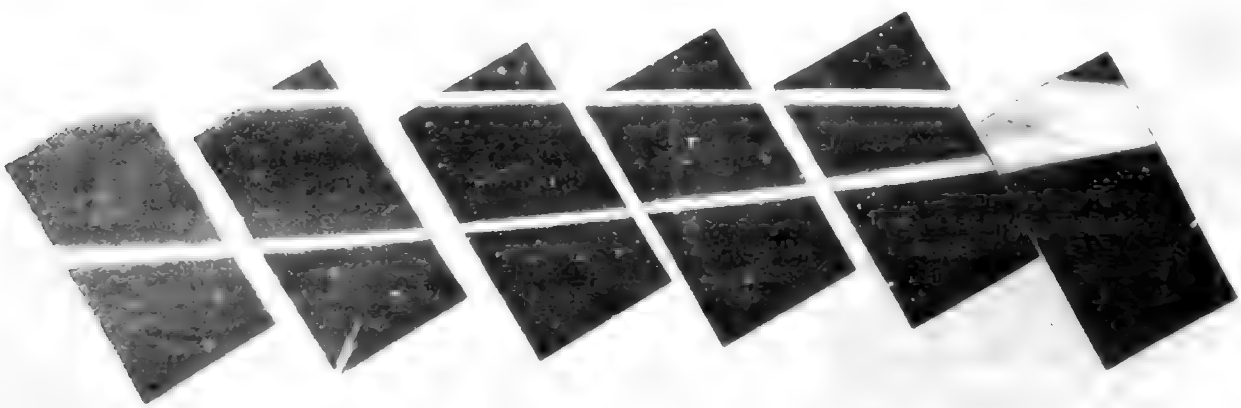
The satellite's orbital period is 7 hours, 8 minutes and moves in its orbit at a velocity of 30 km/sec (67,000 mph). This is the fastest moving satellite known to exist in the Solar System and it has the shortest oribital period.

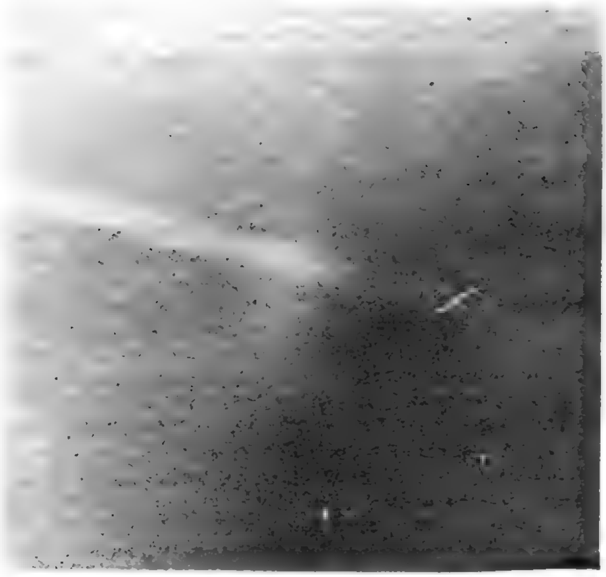
First hint that the apparent star-trace photographed by Voyager 2 was a Jovian satellite came when Jewitt and Danielson, after an exhaustive search, found no star in the vicinity. This led to examination of another Voyager 2 photo of higher resolution showing the same portion of the ring, the same curious object and some trails of known stars. Verification that the object was indeed a satellite of Jupiter was based on the differing angles and lengths of the star trails and the trail left by the target object. From the two pictures, an orbit was calculated independently by Jewitt and by Dr. Stephen Synnott, optical navigation engineer at the Jet Propulsion Laboratory in Pasadena, California, where the Voyager project is managed for NASA. A special analysis of pictures taken four months earlier by Voyager 1 is currently being conducted in an effort to locate the same satellite.

Voyager scientists believe 1979J1, because of its location at the outer edge of Jupiter's ring, may directly influence the composition of the ring either by sweeping out or supplying ring particles.

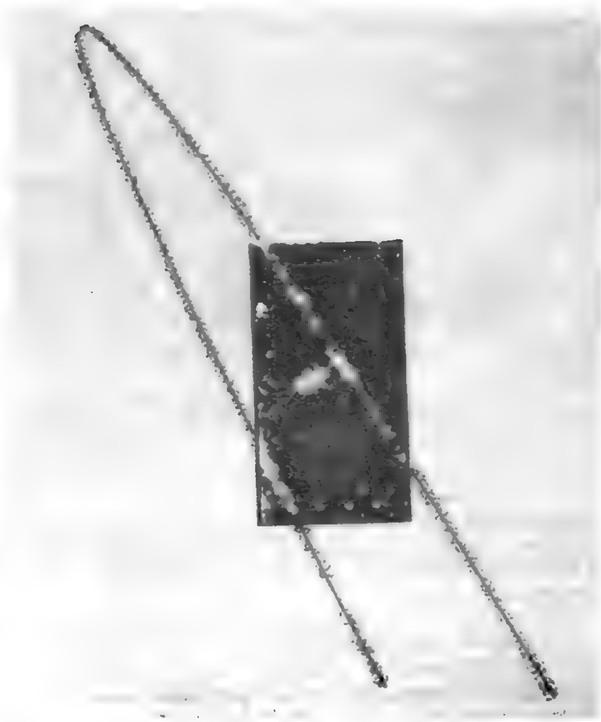
VOYAGER 2 took these high-resolution pictures of Jupiter's ring on 10 July 1979 after flying past the planet. The spacecraft was 2 deg below the ring plane and at a Jupiter range of 961,000 miles (1 550 000 km). The forward scattering of sunlight reveals a radial distribution and density gradient of very small particles extending inward from the ring toward Jupiter.

All photos NASA



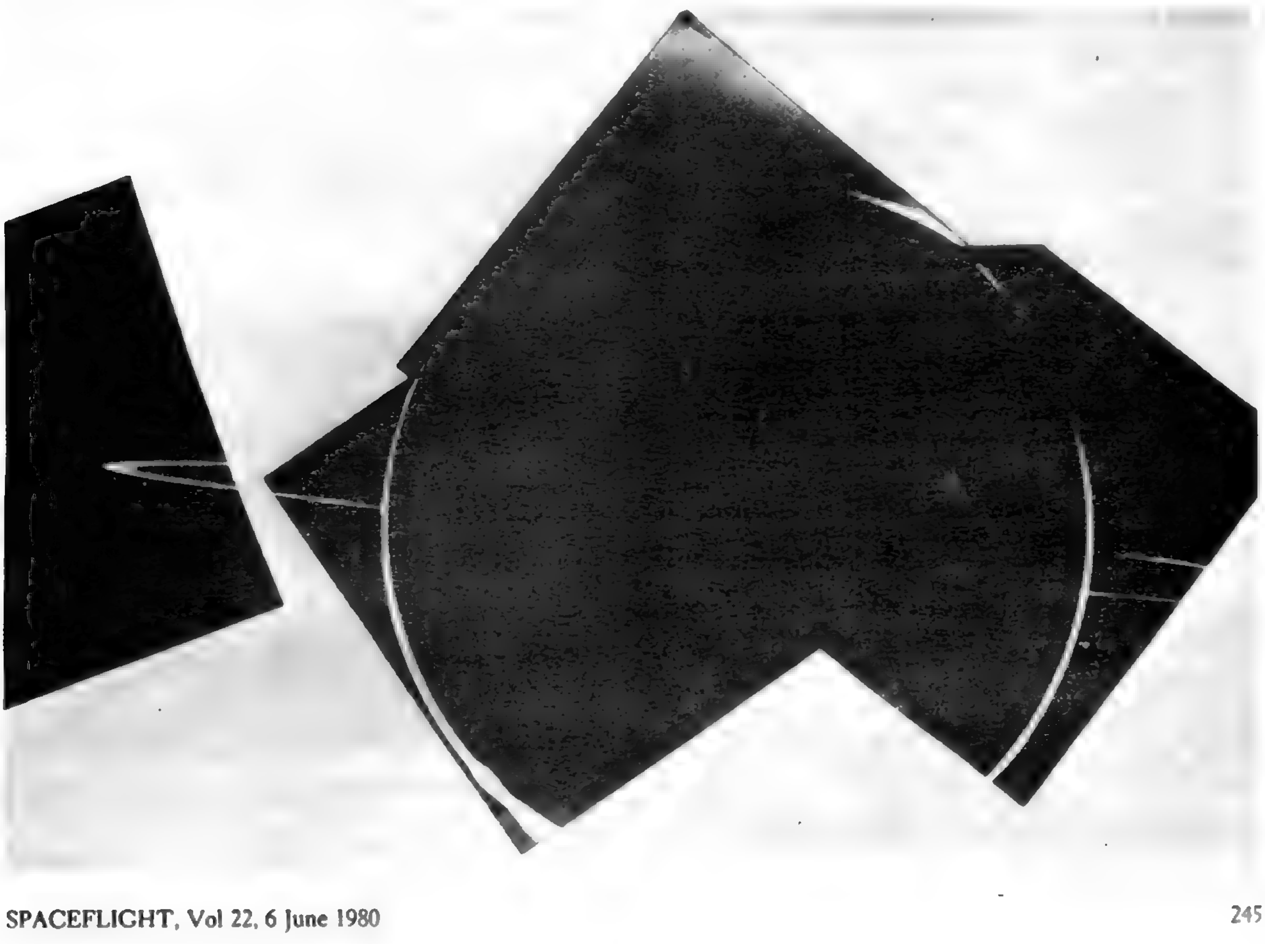


A NEW MOON of Jupiter, the white streak to the right, was revealed in this computer enhanced photograph taken by Voyager 2 on 10 July 1979. The moon called 1979-J1 orbits at the edge of the Jupiter ring seen here as a grey diagonal band across the equator. The other white streak is a star track.



Jupiter's thin ring of particles photographed by Voyager 2 on 8 July from a distance of 1.25 million miles (2 million km). The spacecraft was 2.5 deg above the ring plane.

Below, this four-picture mosaic was obtained on 10 July with Voyager's wide-angle camera while the spacecraft was deep in Jupiter's shadow and some 900,000 miles (1 448 100 km) beyond the planet.



GALACTIC SUPERCLUSTER

Using data obtained from high-flying NASA aircraft, scientists believe they may have discovered the largest cluster of galaxies ever known. And if the indirect evidence is correct, the existance of the suspected supercluster goes back to the beginning of the Universe.

This evidence for the supercluster comes from analysis of measurements from NASA U-2 aircraft of the cosmic microwave background radiation left over from the Big Bang*.

In 1978, a NASA-University of California at Berkeley team used the instrumented aircraft operated by NASA's Ames Research Center, Mountain View, California, to survey remnants of such radiation in the entire Northern Hemisphere sky. A similar survey of the Southern Hemisphere has just been completed.

The University of California scientists used this U-2 data to conclude that our Galaxy is speeding toward the constellation Virgo at more than a million miles an hour. This speed, which is much faster than expected, is attributed to the pull of the supercluster around Virgo.

Astronomers believe the supercluster contains 30 to 40 per cent more galaxies than normally found in the same volume of space, and that it may stretch across some 2,000 million light years of space.

When compared to the 10,000 million-light-year-diameter of the observable Universe, the supercluster would encompass 1 per cent of the volume in it.

Dr. George Smoot of the University of California noted that not enough time has passed since the Big Bang for such a supercluster to have formed. This means that such a gigantic concentration of mass could go back to the beginning of the Universe.

The surveys by NASA aircraft suggest that the event which started the Universe about 15,000 million years ago was extremely regular; that is, a powerful but tightly controlled expansion with matter moving outward in all directions at an equal rate. Now comes the possibility of the supercluster and, "if we have one such huge concentration of matter," says Dr. Smoot, "there are probably others."

This implies that at the time of its formation, the Universe was "lumpy" – that the primordial fireball itself was lumpy instead of being extremely smooth as measurements by the same researchers and others such as Ranier Weiss of the Massachusetts Institute of Technology and David Wilkinson of Princeton University had previously suggested.

The work of other astronomers has contributed to the suspicion of "something unusual in this part of the sky," Dr. Smoot said. X-ray astronomy studies by A. C. Fabian, Cambridge University, and R. S. Warwick, University of Leicester, have found indications of a large-scale structure in the direction of Virgo. J. A. Tyson and J. F. Jarvis of Bell Laboratories have made automated counts of faint galaxies on long-exposure photographic plates and have found evidence of a northern supercluster of galaxies – far more than in any other part of the sky surveyed.

Scientists are surprised at the evidence for a cluster thousands of millions of light years in diameter. Dr. Smoot said it "boggles the mind that such a structure could exist – a big fraction of the observable Universe."

Apparently there is only one such collection of mass relatively close to us. Others, however, may be found at great distances.

California scientists are somewhat disappointed that the finding could disrupt the pattern of a completely uniform Big Bang because a uniform Universe history fits very well with recent work on subatomic particles. "It's a paradox," said Dr. Smoot, "that the Universe is so uniform, but yet it appears to contain non-uniform structures on very close to the largest possible scale."

* *The primordial explosion from which many scientists believe our Universe was created.*

STUDENT ENTERPRISE

Earlier this year a group of students from the Massachusetts Institute of Technology spent several weeks at the Marshall Space Flight Center in Huntsville, Alabama, working on a joint NASA-MIT project studying the simulated in-space assembly of large structures. To perform their experiments they used Marshall's Neutral Buoyancy Simulator, a huge 1.3-million-gallon water tank which allows a close approximation of a zero-gravity environment.

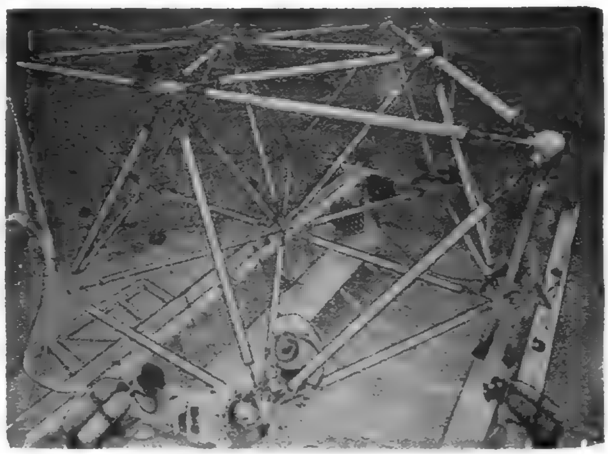
The project called for the assembly in the water tank of a tetrahedral truss containing 48 elements: 36 11-ft-long tubular beams plus 12 joints to hold them together – the largest structure, in terms of number of components, ever tested in the simulator.

Four of the students involved in the project actually worked in space suits in the tank – Dave Akin, Mary Bowden, Mike Floyd and George Sarvar. The others – Kim Lewis, Gardell Gefke and Bob Silverman – served as a support unit.

Akin and Bowden, group leaders for the project, are graduate students working toward their PhD and master's degrees, respectively, in aeronautics and astronautics. The others are undergraduates.

Purpose of the project – called "Payloads for Space" and funded by a grant from NASA – was to generate innovative ideas on the use of the Space Shuttle. MIT is the only educational institution conducting such a study for NASA. All of the equipment used in the experiment was designed, built and tested by the students, several of whom spent the summer fabricating the beams and joints in machine shops at MIT. Before coming to Marshall, they had run the experiment in a swimming pool in Cambridge, Massachusetts, using scuba gear.

Two other students – Eric Shain and Susan Flint – participated in preparing the experiment, but did not make the trip to Marshall. They are busy building an astronaut's manoeuvring unit which the group hopes to test in Marshall's simulator this summer.



SPACE MECHANICS. Working in space suits, Dave Akin and Mike Floyd of MIT assemble a large space structure in the Neutral Buoyancy Simulator at the Marshall Space Flight Center.
NASA

PROBLEMS OF SPACE SICKNESS

The 27th Congress of Aviation and Space Medicine in Manila provided a forum for American and Russian experts to express their perception on the medical aspects of spaceflight, writes Gerald L. Borrowman. Both groups agree that a motion sickness, similar to Earth sea sickness, may afflict future astronauts on long-term journeys. Cosmonauts Dr. Boris Yegorov and Alexei Yeliseyev told a panel at the Congress that the Russians have succeeded in beating motion sickness through the use of a two-hour daily exercise regimen.

Frank Austin, the assistant director of medical operations at the Johnson Space Center, however, disagreed with the Russian claim that the Soviet cosmonauts experience less discomfort in orbit and immediately after landing. Mr. Austin commented: "It (the Russian claim) is a little hyperbole." Austin revealed that the Soviet findings were the product of a simulated six-month marathon that is the equivalent of a year-long round-trip to Mars. Austin said that the health problems encountered by man in space are the result of zero gravity although "prolonged spaceflight produces no damaging effects on the body."

Medical research has shown that astronauts spending prolonged periods of time in space may return to Earth with thinner and weaker bones. Dick Johnston, director of space and life sciences at the Johnson Space Center commented, "This problem (loss of calcium from the bones) is something we would need to consider in very long spaceflights, like a mission to Mars.... Tests of Skylab found that it would take at least nine months to a year before there is any loss in the structural integrity of the bone."

Johnson called the absence of weight as a shock to all the sensory mechanisms as blood rises to the upper part of the body. He speculated the top-heavy-distribution of blood, like hanging upside down from a bar, may be the cause of cosmic motion sickness, When the astronaut returns to earth after a length spaceflight, blood flows back to the lower part of the body in arteries made tense by weightlessness. This may be one of the reasons astronauts experience vertigo or faintness with their first steps on Earth.

In addition to motion sickness astronauts on prolonged missions may experience posture problems from long hours of sitting, calcium loss, slowing of reflexes and a slowdown in red blood cell production.

According to Austin the loss of bone calcium could be linked to the effects of weightlessness on blood distribution. "A lot of blood to the head could send false signals to the parathyroid which provides hormones for decalcification."

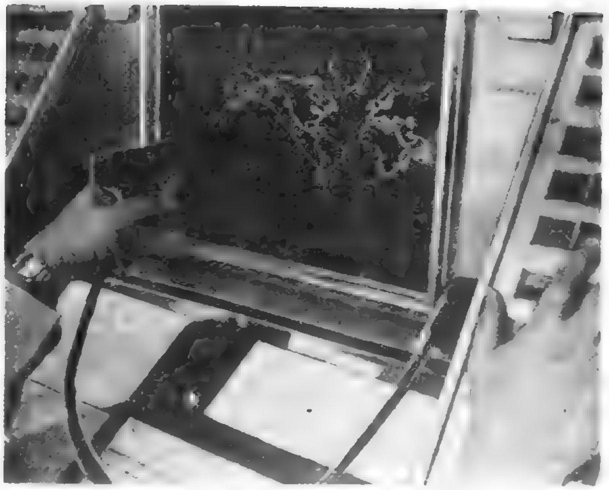
The space and life sciences division of the Johnson Space Center is accumulating information that will make space-station living relatively comfortable. The space Shuttle may be outfitted with a Teflon treadmill and astronauts may also be outfitted with a negative pressure device that creates an "artificial gravity".

NORAD COMPUTER TESTS

Air Force tests of improved computer and communications systems to help direct the defence of the United States and Canada have been underway in the continent's underground command centre in Colorado.

Covering a four-month period, the tests centred on the North American Air Defense Command's (NORAD) computer and communications operations which were modernized in part by the Electronics Systems Division of the Air Force Systems Command.

The equipment is located within the NORAD Combat Operations Center, a facility built inside Cheyenne Mountain in Colorado. The Center is the focal point for receiving data on man-made space objects and aircraft and missile activities.



GROUND TRACK of a satellite called up from the computers at the NORAD Space Tracking Center.

Peterson Air Force Base

The Air Force tested for 24 hours a day, new computers, computer programs, and communications equipment that process information as it comes into the Center. The data was checked for accuracy, and equipment for its capability to process, store and display various types of information.

The equipment involved is housed in NORAD's Command Post, where the organization's decision-makers are located, and in its Missile Warning and Space Operations Center, which keeps track of man-made space objects.

According to Mr. Anthony Salvucci, Electronic Systems Division's program director, "The improvements we've made update an older system we developed back in the 1960s. Since then, NORAD's mission has grown. Some of its equipment needed changing, while others had to be expanded to handle the heavy increases in aircraft, missile and space tracking information.

Among the equipment that required replacement was NORAD's communications processor which feeds information from Air Force organizations and world-wide surveillance sensors, such as radars and telescopic cameras, into the Missile Warning and Space Operations Center and the Command Post. Interruption to the flow of information would be a threat to the entire defence operation.

Now, an automatic "health check" switching system constantly watches the performance of communications equipment and transmission lines. If performance drops below standards, the monitor automatically switches the information coming in to back-up equipment or lines. Previously, as information on man-made Earth-orbiting objects came in, it was stored in computers in the present Space Defense Center.

The facility had no displays, so data was available only in printout form. If details on a satellite's position were needed, a technician would ask the computer for its latest output, request an update if necessary, review the data, then forward information of interest to Command Post officials. The procedure was time-consuming and there was always a possibility of human error.

Technicians in the new Missile Warning and Space Operations Center can now request a satellite's position on any of eleven display consoles, instantly compute its orbit, analyze the data and pass on critical information to the decision-makers on their Command Post consoles – all in a matter of a few minutes.

THE MANNED ORBITING LABORATORY Part 2

Engineering Details and Experiments, circa 1964

Continued from April 1980 issue page 160.

By Curtis Peebles

A footnote in history

Among the space projects undertaken during the 1960's, certainly the most obscure was the US Air Force's Manned Orbiting Laboratory. Part of the reason is the extreme secrecy surrounding MOL because of its mission of manned orbital reconnaissance. Thus there were none of the reams of technical data as with Mercury, Gemini, Apollo or Skylab; only the barest details of size, mission and technical features. With the programme's cancellation, it would be reduced to a footnote in history. The first attempt by the United States to develop a long duration manned space station deserves better.

MOL Mission and Goals

The Manned Orbiting Laboratory was to be an experimental space station to provide data on the military usefulness of man in space. Also, to determine the role of man in future operational military space systems and how best to use the capacities of a human crew for maximum effectiveness. To this end, the mission's experiments were to focus on the role of man in the system, on missions that could not be undertaken otherwise, to confirm ground and airborne test data and to cover the entire spectrum of potential military missions.

The MOL was a three-part integral unit: the Gemini B which was to carry the two-man crew into orbit and return them to Earth; the laboratory module which supports the crew and some experiments for the 30-day baseline mission and the unpressurized test module which houses the remaining experiments.

It would be launched into low Earth orbit by a Titan IIIC. (after the programme formally began, weight increases necessitated a change to a Titan IIIM booster). Once MOL was successfully placed in orbit, the astronauts, from the Gemini B, would conduct a check-out of the essential lab sub-systems and activate those sub-systems which must be on for transfer.

In mid-1964, the exact means of transfer, from the Gemini B to the lab, were under study. After entry to the lab, the crew would activate the remaining sub-systems. Once the lab vehicle was in a fully operating condition, the crew would remove their spacesuits.

The Gemini B would be placed in a dormant stand-by status. The crew would have flight control and be the primary source of the on-orbit decisions.

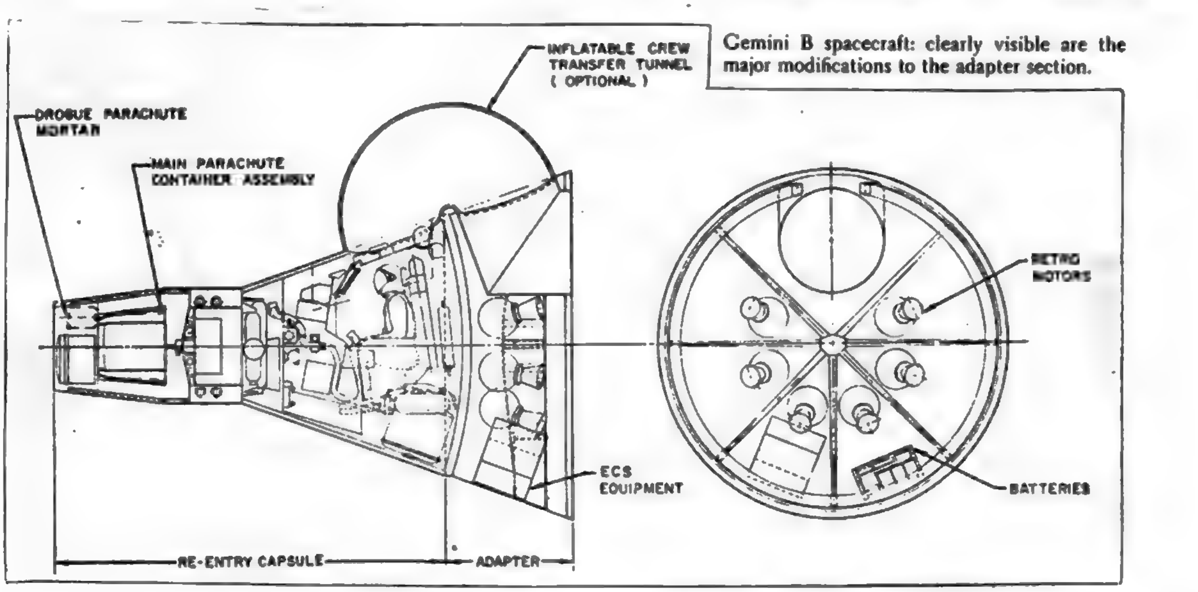
After the 30-day mission was completed, the astronauts would perform final checks of the Gemini B and activate the transfer systems. The crew would put on their spacesuits, activate certain lab systems and complete their transfer. The Gemini B would then separate from the lab and orient itself for retro-fire. After re-entry, it would deploy a parachute and make an ocean splash-down.

Gemini B

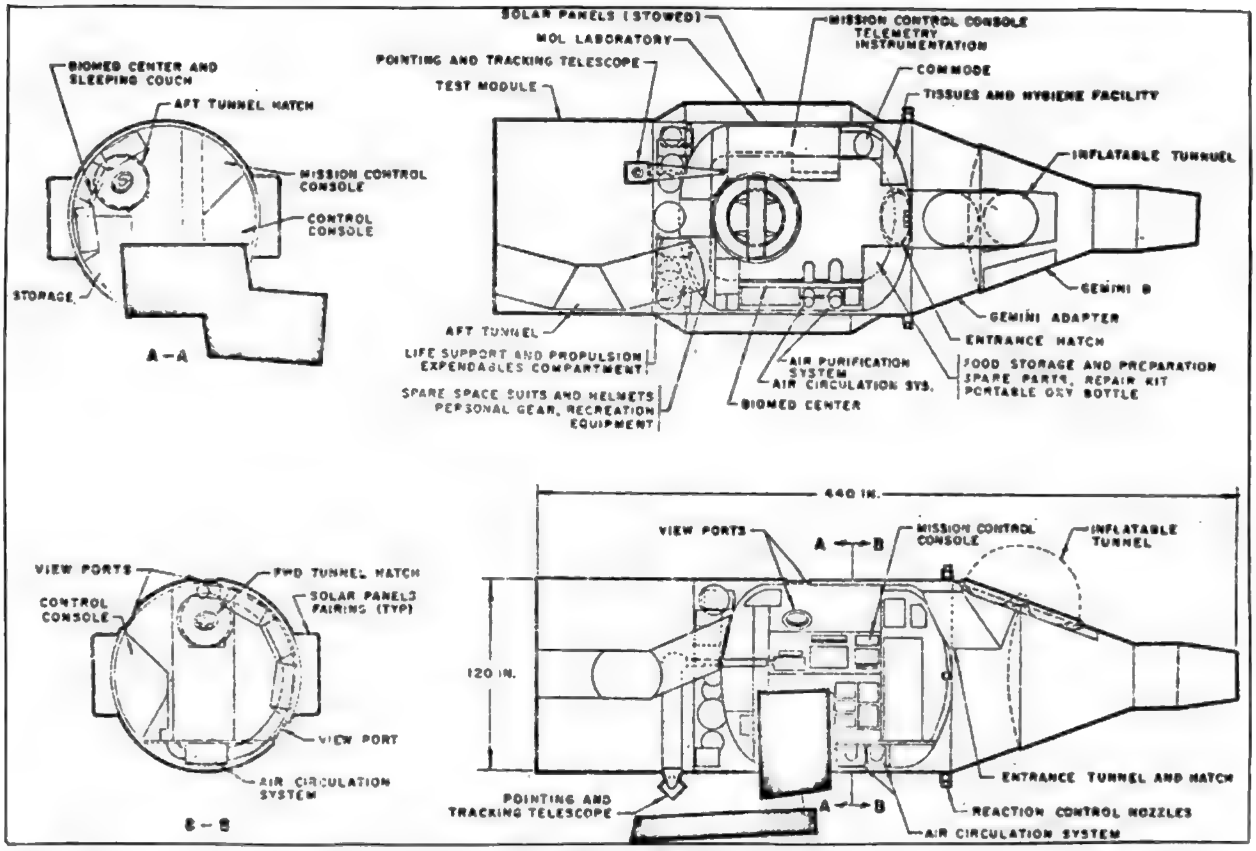
The Gemini B was a modified version of the NASA Gemini spacecraft. It was composed of a re-entry capsule and an adapter. The capsule was very similar to the NASA version except for modifications necessitated by the change in mission profile. This would include the capacity to activate lab systems and provisions for astronaut transfer. Of the four transfer concepts under study in mid-1964 (inflatable tunnel, EVA, hatch in the heat shield and rotating the Gemini) only EVA required no significant changes in design. The others would necessitate changes in the heat shield or access hatch. Rearrangement of equipment in the re-entry capsule would be necessary, as well as the addition to the adapter of tunnels or mechanisms. The inflatable tunnel would require slight strengthening of the Gemini structure. Transfer was an important factor to be considered since it affected the design and structure of both the Gemini B and Lab. An increase in heat shield thickness was contemplated to enable the Gemini B to handle a wider range of re-entry conditions adding some 20 lb. (9 kg). The adapter was to be a new system; it would contain the retro-rockets, power and life-support systems.

Sub-systems, not directly required for MOL, could be retained to take advantage of NASA's development and tests. This included the Gemini life-support system, orbital attitude and manoeuvring systems and the inertial guidance system and rendezvous systems.

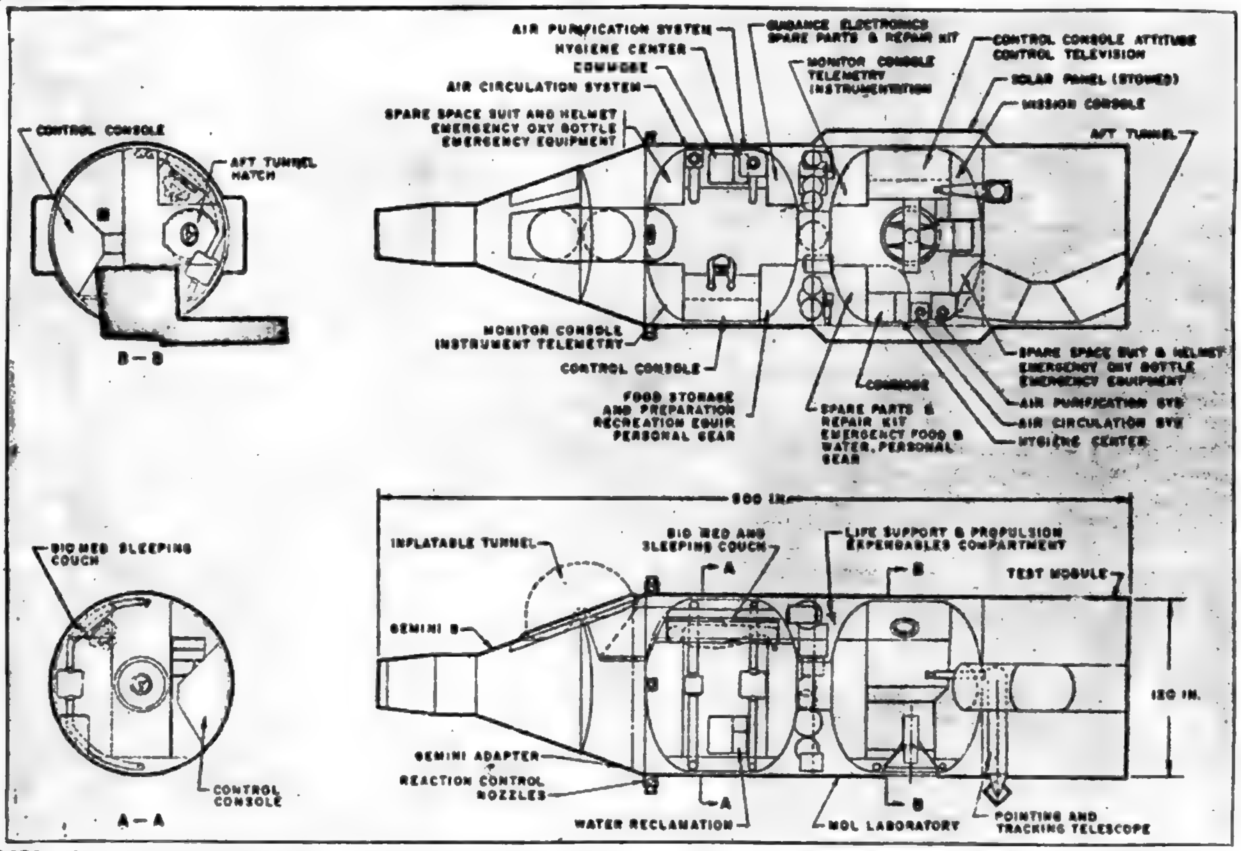
Because it was to act as a transfer vehicle, the Gemini B was active only during launch and re-entry. A monitoring and



Gemini B spacecraft: clearly visible are the major modifications to the adapter section.



MOL vehicle single pressure compartment. At this time – mid-1964 – the inflatable tunnel transfer method was viewed as one of the more promising.



MOL vehicle using a dual pressure compartment. This is believed to be similar to the design ultimately chosen.

check-out provision would be necessary for the Gemini B during the semi-dormant storage period. The lab vehicle would provide power and life-support during this phase. It may, also, have been necessary to add the capacity to the Gemini to return small data packages from orbit. The 30 days of semi-dormant storage, also, could necessitate the replacement of cryogenic storage bottles with high pressure bottles and fuel cells by batteries.

The need to re-activate systems in preparation for re-entry could require the addition of redundant sub-systems or replacement by simpler, more reliable components. The Gemini inertial guidance system could, also, be replaced by a simpler unit for attitude reference for retro-fire and re-entry. The existing IGS could be used during the launch phase as either primary or back-up.

Finally, because the MOL's orbit was higher than a NASA Gemini mission, an uprated retro-rocket system was necessary. It was not, however, the Air Force's intention to re-invent the Gemini. It was stressed that the most efficient use was to be made of NASA's resources and NASA Gemini planning hardware test results and opportunities for training. Development of new equipment was to be held to a minimum. An early estimated weight break-down of the Gemini B was as follows:

Re-entry Module	4,372 lb
Structure	1,407
Heat Protection System	318
Attitude, Stabilization and Control	359
Retrograde, Landing and Recovery	217
Navigation Equipment	138
Tele-Instrumentation	113
Electrical Power System	277
Communications System	58
Crew and Survival	940
Miscellaneous and Contingency	220
Adapter Module	1,628
Structure	290
Crew Transfer System	180
Retrograde System	509
Electrical Power System	200
Environmental Control System	257
Tele-Instrumentation	88
Miscellaneous and Contingency	104
Total Gemini B weight in orbit	6,000

Laboratory Vehicle

The laboratory vehicle was composed of two parts: a pressurized lab area, in which the two man crew would live and work for most of the 30-day mission, and an un-pressurized test module which would contain the bulk of the experiment equipment. Attention was paid to the best configuration for the lab. Both 1 and 2 compartment designs were studied. It was believed that separation of the volume into two compartments would increase the probability of crew survival but significant weight penalties could be involved necessitating a trade-off between crew safety and mission performance. Ultimately, a compromise was selected – a 1-segment unit, with a common floor, divided into two units.

Because of the long mission duration, an adequate volume of working and living area was necessary. A minimum goal of 200 cubic feet (5.66 cubic metres) per astronaut was selected for initial studies making it the roomiest of any US spacecraft to that date. Experiment controls and monitoring equipment was grouped in the rear portion of the lab.

There would be an air circulation and purification system; also, an area for food storage and preparation. Long duration flight posed unusual problems such as effective stowage of the some 180 meals necessary for the mission. One cabinet would hold necessary spare parts and a repair kit. While in space, the crew would undertake medical tests to determine the effect of 30 days of weightlessness. The biomedical centre was designed for this important study. It would have the necessary sensors for electrical, mechanical and chemical measurements, signal analyzers, converters and data recorders. Samples would be preserved for analysis after the crew's return. It would be equipped to make simple chemical tests. One member of the crew would receive training to conduct the tests. The biomed couch would also be used for sleeping. Data could be recorded by real time TV or motion pictures. There would be storage for a spare spacesuit and helmet, oxygen bottle, emergency equipment, emergency food and water, as well as personal and recreational gear.

All would be grouped for best utilization, access and function. External equipment included reaction controls, thermal controlled radiators, communications and tracking antennae and experiment equipment. The structure would be a foam-filled aluminium truss core sandwich material.

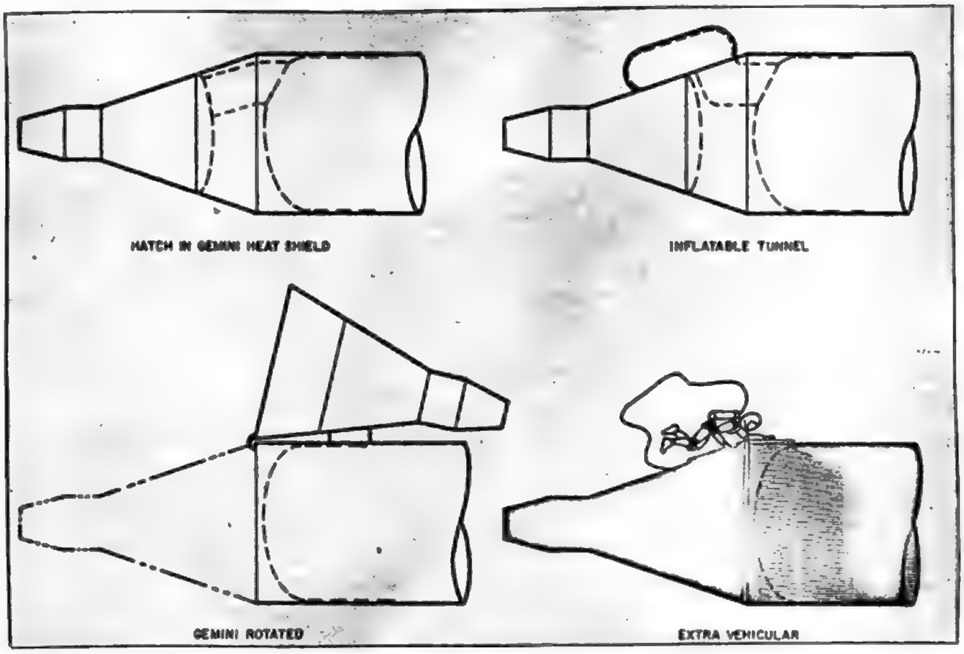
A tunnel in the test module allowed emergency access to the pressure compartments. This, also, allowed a spacesuited astronaut to reach and carry out maintenance on the test module experiments. Several operating and display consoles would be required for monitoring and checking out each of the vehicle's sub-systems. These would be designed to provide means of monitoring critical components and automatic warning indicators. They would assist in the isolation of system malfunctions and so enable the crew to undertake repairs. The consoles for MOL would be limited in size and weight. If MOL was to be given a manoeuvring capacity, there would be a need for displays in either the Gemini B or the Lab and "pilot in the loop" controls to the engines. A preliminary breakdown of the weight of both vehicles was the following:

Element	Weight (lb)
Gemini B plus adapter	6,000
Laboratory Vehicle (Pressurized)	5,910
Test Module (Unpressurized)	1,150
Experiment Payload Available	5,940
Weight Contingency	2,000
Sub Total	21,000
Dry Transtage (If retained)	4,300
Total	25,300

The Gemini B weight listed was only the basic capsule and adapter with no autonomous orbit capacity. A 2,000 lb (907 kg) contingency has been added to allow for vehicle weight growth, normal in such projects. A further, 2,000 lb (907 kg) allows for any drop in performance of the Titan IIIC. If orbital manoeuvring was to be part of the mission, the weight of propellant must come out of the experiment weight budget. A manoeuvring capacity could be provided either by the Titan IIIC transtage or low-power thrusters. The crew's capacity and limitations had a direct affect on vehicle weight, volume, flexibility and cost. The crew could undertake on-orbit maintenance; primary emphasis, however, was to be on redundancy to accomplish mission goals. Bioastronautic experiments were expected to be manual. Military experiments would be semi-automatic and would take advantage of the astronauts' capacity to calibrate, select, monitor and partially control. A representative two-man duty cycle for a 30-day or longer mission would be

The Manned Orbiting Laboratory – 2/contd

Astronaut transfer methods. The hatch in the Gemini heat shield was the system ultimately selected.



Task	Man hrs/day
Sleep	16
Eat	2
Exercise	2
Hygiene	2
Leisure	3
Station Operation	4
Experiments	11
Maintenance	4
Miscellaneous	4
Total	48

The life support system for MOL had four major features: a low-pressure two-gas atmosphere, temperature control by heat exchanger, carbon dioxide absorption by a silica-gel molecular sieve and trace contaminate removal by absorption and catalytic burning. Sub-critical cryogenic storage was believed to be desirable. There were no provisions for artifical gravity. The life-support system would include food provisions, waste disposal, hygiene and probably water recovery.

Electrical power requirements of the MOL during normal operations was estimated at 1.2 kWs not including the experiments or the Gemini B. There would be brief high-power level requirements for some of the experiments. These requirements could be met by fuel cells but solar cell arrays/batteries were also considered.

The MOL would be outfitted with transmitters, receivers, beacons, antennae and auxiliary equipment necessary for space-to-Earth voice communications, experiment and spacecraft telemetry, TV, tracking and command communications. Docking provisions for MOL were under study because of astronaut rescue and/or system growth. Three different modes were considered: tail to tail, side by side and nose to tail. Comparisons were made with regard to cargo transfer, ease of vehicle approach manoeuvres, drag area of the docked vehicle and design implications on the Gemini B and Lab vehicle. A universal docking and mooring mechanism, as well as related structural and space provisions, could be added to the aft end of the test module. Whether manoeuvring and docking was to be added during the initial phases or later would depend on trade off studies of the cost in dollars, weight and complexity.

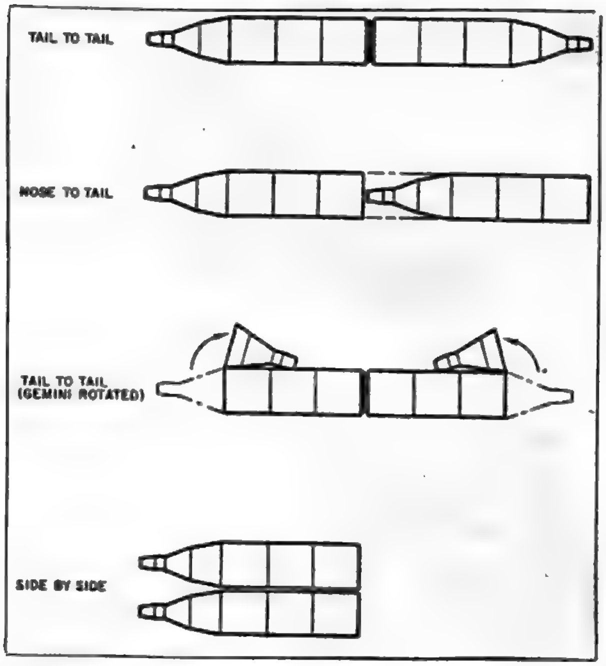
A preliminary breakdown of a typical single pressurized compartment design was as follows:

Sub-system or Item	Weight (lb)
Electronics	335
Leak Detection System	50
Electrical Distribution System	150
Heat Rejection	292
Air Circulation System	158
Pressure Suits and Suit Circuits	160
Atmosphere Resupply	989
Water Management	172
Waste Management (Including Disposal System)	50
Food	216
Cleaning Materials	24
Disposable Clothing	24
Reaction Control System	306
Solar Array System	824
Laboratory Structure	1,685
Displays and Furnishings	345
Spare Parts	130
Laboratory Module Sub total	5,910
Test Module Structure	1,150
Experiment Payload	5,940
Sub total	7,090
MOL Vehicle Total	13,000

From available information, it is believed that this weight breakdown was typical of those at the time of programme approval in August 1965.

Experiments

MOL's experiment load was a critical design factor; they determined the vehicle's power requirements, attitude control, sub-system design, test procedure and other vehicle consid-



Alternative docking and mooring methods for the Manned Orbital Laboratory.

All illustrations courtesy US Air Force

erations. It, also, had political importance. It was apparent, quite early, that MOL would not be approved by the Secretary of Defense unless the experiment package could clearly demonstrate qualitatively and quantitatively the military usefulness of man in space. To do this, the MOL would have to undertake tasks similar to those of an operational military space station; such things as: manned orbital photo reconnaissance, electromagnetic reconnaissance, early warning and ocean surveillance, among others. It is not particularly surprising that the procedures, equipment, weight, volume, power and attitude control requirements of such experiments are still, 16 years later, considered secret information.

By mid-1964, 12 primary experiments and 18 secondary were under study. Of these, 6 primary and 4 of the secondary ones have been deleted from the reference document. Primary experiments, P-1 through P-4 fall into this category. P-5 is in-space maintenance, testing man's capacity to detect malfunctions, repair and maintain military equipment. It would involve experiment P-4's equipment and use a malfunction detection panel for fault isolation, spares, tools and a portable check-out unit.

Two types of malfunctions would be studied – erratic or sub-standard operation and complete failure. The failed chassis would be located with the malfunction detection panel; then the astronaut would use the portable check-out unit to find the particular module element to be replaced. Data would be recorded on film.

P-6 was a study of EVA; first the external maintenance tasks (replacement, connecting, patching and retrieval) would be simulated inside the lab. Later, they would be done in free space. The tests would use a manoeuvring unit and would involve both tethered and un-tethered procedures. At each step, the demands of the tasks would be determined as part of the test of man's over-all ability to perform EVA missions.

P-7 was a test of an astronaut's ability to control a remote manoeuvring unit (RUM) en-route to and in the vicinity of a target satellite. The RUM was a package remotely controlled by an astronaut in the MOL. It had its own propulsion and attitude control system. It was controlled by use of a console and a display of the TV picture. The RUM weighed some 300 lb (136 kg). It would be useful as both an inspector and for re-supply of other spacecraft.

P-8 was a test of space navigation without the use of ground control. The equipment involved would be a set of horizon scanners, a precise time reference, two star trackers, prepared navigation data, a pointing and tracking scope and a digital computer. All, except the two star trackers, were available from other experiments. The pointing and tracking scope and digital computer were from P-1. Two of many typical experiments would involve locating a well-known landmark with the pointing and tracking scope. Then two stars, suitably located, would be selected and the star trackers locked on. The angular relationship between the stars and the landmark would be fed into a computer and a rough orbit determined. A repeat of the procedure would refine the orbit. From this, predictions of future positions could be developed.

The reverse could, also, be performed. From a known orbit, the position of the landmark could be established. The characteristics of a gradually changing orbit (due to atmospheric drag or other poorly understood reasons) could also be determined. The orbital track was to be predicted from on-board data, the time angular relationship of the local vertical and several check points being computed. As each check point was reached, the tracking and spotting scope was pointed at it and the angular data, from the scope and horizon scanners, fed into the computer. The small differences between predicted and actual position were to be used to determine the orbit. The information could then be used to compute necessary orbit changes and after the manoeuvres were carried out, to check the resulting orbit. The experiment would test the astronaut's tracking ability, the ability to locate and lock-on stars, his ability to judge the navigation procedure best suited to the situation, use of computer and displays, to perform graphical checks on the computations and his ability to conduct orbital navigation.

Experiments P-9 and P-10 were deleted.

P-11 was a test of general performance in military space operations. It would use a standard test battery to measure the performance and physiological changes caused by prolonged weightlessness, confinement, work load and diurnal variations. The tests would involve procedures to measure vision, heart, monitoring and processing information, mental computations, perceptions, decision making and three-dimensional tracking. The tests would be taken throughout the work/rest cycle. Results would be compared to ground test data.

P-12 was the biomedical experiment to measure the physical effects of weightlessness using the Biomed Center. Tests would be on blood volume, pressure and flow, heart behaviour, fluid balance, nutrition, metabolism and nervous system functions.

S-1, the first of the secondary experiments, was a communication propagation experiment between the MOL and globally distributed ground stations. The MOL would record transmissions from ground stations and signal profiles determined. Monitoring of a particular transmission would be conducted for one full orbit to see if reception was continuous and world-wide; then later for shorter periods. MOL's transmissions would be received by ground stations. It would require a tuneable receiver, transmitter, a variable-length antenna, earphones and recorders.

S-2 was secure communications using narrow beams which was to test a MOL/aircraft and MOL/ground radio link. It would answer questions about use of narrow beams for voice communication between moving terminals. The two parts could be flown on separate MOLs and would operate at different frequencies.

S-3 was deleted.

S-4 was a test of ionospheric ducting communications. This was to test beyond line-of-sight communications between MOL and ground stations and aircraft using a panoramic receiver, transmitter and graphic recorder. The astronauts would detect and monitor signals and establish communica-

The Manned Orbiting Laboratory – 2/contd

tions with ground stations and aircraft. These would determine whether the two-way links were global and continuous. The experiment would indicate the number of ground stations necessary for continuous communications and the frequency and power requirements. It would, also provide information on poorly understood ionospheric effects.

S-5 was deleted.

S-6 was a test of expandable structures. Four expandable structural cylinders would be used: an airmat, an expandable self-rigidizing honeycomb, a foamed-in-place structure and a telescoping structure. Each would be pressurized to cabin pressure and be inspected by the astronauts. Also to be carried, were two small expandable solar collectors. This experiment would indicate the usefulness of expandable structures for such purposes as complete space stations or their components, solar collectors and antennas.

S-7 was deleted.

S-8 was a test of an advanced rendezvous radar and man's function during close-in rendezvousing and docking.

S-9 was deleted.

S-10 was a mapping and geodetic survey for identified points. It was cancelled as it duplicated P-8.

S-11 was the determination of the mass of a satellite. Two separate systems were to be used. The first was a rocket propelled net. The MOL/target range would have to be between 500 and 1,000 ft (152 to 305 m). The other was an automatic shotgun firing small nylon pellets: maximum range was to be approximately 150 ft (45.7 m). Both used momentum transfer to determine inertial mass. The target's relative velocity must be measured before and after by radar. The crew would aim and fire the systems and transform range rates into mass and determine the amount of undesired damage to the target.

S-12 was a test of hydrogen reduction atmospheric regeneration. It was to use a life-support system that would reduce CO_2 to H_2O and an electrolysis sub-system which would break the water into hydrogen and oxygen. Water and CO_2 removal systems were, also, included to make a complete atmospheric regeneration system.

S-13 was a water recovery system. Water would be boiled and then the vapour would be compressed, then condensed. Impurities would be removed by a liner in the evaporator. The lining would be replaced every two weeks between batches.

S-14 was a test of passive propellant settling systems. It would use surface tension to control liquids in tanks during prolonged periods of weightless flights. Equipment was to be several transparent sub-scale tanks containing various liquids and control devices. They would be photographed at regular intervals over the course of the experiment.

S-15 was a test of the distorting effect of the ionosphere on radio signals and to investigate antenna loading under space conditions.

S-16 was a solar X-ray warning system. It would be used to forecast lethal high energy proton showers. If the level should exceed a pre-set value an alarm would sound.

S-17 was materials degradation to test the effects of space on selected MOL components. The primary purpose was to determine the cause of failure. A secondary purpose was to investigate whether the strict specifications on materials were, in fact, necessary. Components would include bearings, thermal control surfaces, solar cells, lenses, windows, filters, mirrors and metal surfaces.

S-18 would be multi-band spectral observations of the planets. Portions of the infra-red spectrum of Venus and Mars would be scanned to determine the thermal and chemical structure of their atmospheres. Low resolution scanning would be done over the entire spectrum available. High resolution scans would be done in selected bands in the 3 to 4.5 μ and 7 to 15 μ range. Long integration times would be required up to 30 minutes.

Vehicle requirements for the primary experiments were as follows: 2,712 lb (1,230 kg), 78 cu ft (2.2 cu m), 1,000 watts of power and 2,000 ft/sec (609 m/sec) manoeuvring capability. For the secondary experiments: 3,000 lb (1360 kg), 104 cu ft (2.94 cu m), 1,800 watts and 200 ft/sec (61 m/sec) of manoeuvring capability. Weight was all equipment, volume was only that inside the MOL laboratory module. Power was the maximum single requirement. The manoeuvring requirement was set by experiment P-2. This would require nearly the entire weight budget to be devoted to fuel. The 5,940 lb (2694 kg) of experiments could provide 2,500 ft/sec (762 m/sec) of manoeuvring capability with the transtage. Because of the secret nature of the experiments, secure de-orbit or secure disposition of the lab was necessary. This was the status of the experiments as of mid-1964 and like MOL, itself, would undergo changes. Some experiments were either cancelled outright or combined with others.

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Space Systems Division, Air Force Systems Command.
Released under the provisions of the Freedom of Information Act.

ASTRONOMICAL NOTEBOOK

By J. S. Griffith*

SOLAR SYSTEM

Solar activity over the last 2000 years

On examination of reports of auroral displays in classical literature it was found that, providing solar activity has always been responsible for aurorae, the solar cycle two millenia ago was very similar to what it is at the present.

The author of ref. [1] draws attention to various phrases in classical literature that may tentatively be considered as manifestations of aurorae. These phrases include "chasms", "sky fire", "night suns", "blood rain", "milk rain", "beams", "pillars", aurora-like "torches", and aurora-like "comets". Following a time series analysis of the data, which was designed to overcome problems of incompleteness and mistaken identifications, a period of 11.5 years was deduced. As aurorae are caused by the interaction of the solar wind with the Earth's upper atmosphere, the ancient auroral cycle can be directly related to the ancient solar cycle, implying a certain regularity of the Sun's rhythm over 2000 years.

It is also pointed out that direct observations of solar variability in ancient times are of doubtful validity – "there seems to be reasonable doubt that either sunspots or the solar corona was ever observed in the ancient West". However sunspots were certainly reported in China during the same period (ref. [2]).

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Rings of Uranus (and Mars?)

The nature and origin of the rings of Uranus with their narrow widths and sharply defined edges are explained in terms of material from the surface of satellites within the Roche zone losing material to form the rings and providing a gravitational resonance which defines the narrow, sharp-edged rings. A similar phenomenon is predicted to occur for Mars as Phobos, which is now probably just within the Roche zone, loses it loose regolith and provides Mars with its ring.

In ref. [1] the effects of a resonance between a set of ring particles containing a satellite is considered. For Uranus the satellites have as yet not been discovered. It is suggested that the rings of Uranus are caused by small satellites that have entered the Roche zone due to tidal drag. The narrow orbital radii range of the rings fits well into the Roche zone, where the satellites are expected to be losing material from their surfaces. This material enters orbits similar to that of the satellite and is compelled to remain in a narrow, sharply defined ring by the gravitational force of the satellite.

The extent of the Roche limit (the distance from the planet at which a satellite suffers tidal loss of particles or disruption) depends upon the properties of the material and shape of the satellite as well as its density.

Phobos, the inner satellite of Mars, provides a good model for the ring satellites postulated for Uranus. It has a regolith of loose material of depth up to 200 m and is well below the synchronous orbit of Mars, with tidal dissipation within Mars itself causing the orbit to decay so that, unless the satellite partially disintegrates in the Roche zone, it will strike Mars within 10^8 years. At present it is just within the Roche zone, and as its orbit decays loose material will probably leave the satellite's surface and form a narrow sharply defined ring. This ring will be eccentric and inclined to the equatorial plane of Mars. If such a sequence of events has already occurred around Uranus with each ring containing a small satellite then most of the observed features of the rings can be accounted for.

It is noted that Neptune also has a Roche limit well within its synchronous orbit and may have rings, as is also possible for Europa, Ganymede, Callisto and Titan.

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STARS

AM Canum Venaticorum

This cataclysmic binary has at various times been considered to be a quasi-stellar object, a massive helium star, a rotating or pulsating subdwarf, a DB degenerate dwarf, and a cataclysmic variable. Recent observations are analysed and the cataclysmic variable seen to be the only model capable of explaining the host of diverse phenomena seen in the star. Both components are much smaller than Jupiter (which itself emits more energy than is incident from the Sun).

For several years the authors of ref. [1] have been accumulating photometric data on AM CVn. The 17.5 minute orbital period is increasing, probably due to mass transfer which is expected to cease in about 10^8 years, leaving a white dwarf and a planetary sized object orbiting around each other. It is predicted that the system is a strong EUV/soft X-ray source.

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Thermonuclear events on neutron stars.

Numerical models of what happens as neutron stars accrete hydrogen-rich material are presented. Heating of the neutron star envelope by hydrogen burning leads to the ignition of helium and an X-ray burst, resembling some X-ray burst observations.

Recently short-time-scale transient phenomena in the X-ray region of the electromagnetic spectrum have generated interest. With rise times of less than a few seconds, durations from several seconds to a few minutes, 10^{38} ergs of peak burst intensity if at 10 kpc, and distributed with a concentration towards the galactic centre, many of the bursts repeat after a few hours or a few days.

The time-dependent burst spectra, in some cases, can be fitted by a cooling black body or radius around 10 km. The authors of ref. [1] model the outbursts by accretion of material by a neutron star. The overlapping of the hydrogen and helium burning shells lead to thermonuclear flash instabilities, and provide the energy for the X-ray burst.

Further work on the details of the thermonuclear flash with respect to variations in stellar parameters is needed, as are reaction rate studies.

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INTERSTELLAR COMMUNICATION

A biological extraterrestrial message?

Numerous authors have discussed the possibilities of using electromagnetic waves for interstellar communication. Another medium for information exchange may be biological! It is suggested that a plage DNA is prepared that proliferates actively

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and carries an intelligent message encoded in its base sequence. This DNA is then sent directionally or isotropically to other civilizations.

In ref. [1] it is noted that the advantages of a biological probe include self-replication on arrival, low signal-to-noise problems with mutants selectively weeded out so long as the genetic structure of the plage (or microbe) is perfectly adapted to its environment, ease of reception and long life time.

Disadvantages include translation (where the society must have a common biochemistry) and interpretation.

The authors of ref. [2] examined 0X174 DNA to see if a message was encoded. Plage 0X174 is a virus infectious to an enteric bacterium inhabiting the colon of the only intelligent beings on Earth, and its genetic material is one of the smallest known.

Unfortunately, after proposing this intriguing idea, the authors were unable to detect any message.

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GALAXIES AND QUASARS

Neutrino astronomy, quasars and the nearest quasar?

It is pointed out that many active galactic nucleii may be detectable as point sources in high-energy neutrinos with the aid of the proposed neutrino "telescopes". The overall cosmic neutrino background due to active galaxies may be orders of magnitude above the threshold of detection.

The Seyfert galaxy IC 4329A was studied spectrophotometrically using the Anglo-Australian telescope. It was found to resemble lower-luminosity quasars and gives us an opportunity to discover other properties of quasars.

In ref. [1] the observations are described and discussed. The nucleus of IC 4329 is heavily reddened by a prominent dust lane bisecting the nucleus, and contrary to some theoretical speculations, the interstellar medium is not seriously disrupted.

Among the most exotic objects in the Universe are active galactic nucleii, and quasars are probably very bright, distant active galactic nucleii with other members of their family including radio galaxies, Seyferts and N galaxies. In ref. [2] the non-thermally driven infrared emission from active galactic nucleii is shown to be transformed by pion-producing collisions and absorption in the nucleii into high energy neutrinos (the primary decay product of charged pions) with a power comparable to the total power radiated by the nucleus.

Even though many nucleii may be obscured by surrounding matter and radiation fields, these fields convert the energy of high-energy particles into neutrinos and antineutrinos. A neutrino telescope may indeed be able to record the earliest stages of explosions in quasars. The most sensitive neutrino "telescope" being considered is the Deep Underwater Muon and Neutrino Detector (DUMAND), ref. [3] using about 10^{10} tons of sea water, and should average 200 counts a day at energies over 10^{12} eV.

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The knots in the M87 jet.

It was found that the polarization and intensity of knots in the jet of M87 have changed over the past 22 years. There is a remarkable similarity between the properties of the knots and those of BL Lacertae objects, which appear to be found preferentially near bright galaxies.

The jet in the giant E galaxy M87 (NGC 4486) is presumably luminous matter ejected from the galaxy. It consists of a series of six discrete knots superimposed on a narrow band of luminous material, with the knots having a complex structure.

A radio wavelengths of jet emerges from a compact radio source at the centre of M87 only a few light months in diameter, with each knot being a discrete radio source.

Using methods as similar to those used 22 years ago by W. Baade (with the 5 m Hale reflector) the authors of ref. [1] repeated his observations. Changes in polarization and intensity were noted, as was the similarity between the appearance and radio spectra of the knots and those of *BL Lacertae* objects. The masses of the knots seem to be greater than 10^7 solar masses.

The M87 nucleus itself is compact and active, being an X-ray source and optically variable.

If the recently reported (ref. [2]) high velocity dispersions in the innermost regions of the M87 nucleus do indeed signal the presence of a black hole, it is tempting to explain the ejection of the jet in terms of a slingshot mechanism (ref. [3]). Black holes undergoing an orbital encounter can utilize their orbital energy to eject themselves in opposite directions from the nucleus, and there is evidence for a counter jet (ref. [4]). However the authors of ref. [1] point out that the observations of the M87 phenomena are much more characteristic of white-holes.

Further observations include the detection of additional jets, representing the M87 scenario at a later epoch, and to determine if the massive nature of the knots does influence the velocity fields of stars near them.

With the high resolution of the space telescope it is hoped we can gain a better understanding of the nature of the knots.

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TELESCOPES

Lobster eye telescopes?

Using optics based on the reflective eyes of macruran crustaceans (lobsters, shrimps and crayfish) where the eye consists of a number of small tubes of square cross-sections, with reflective internal surfaces, arranged over a spherical surface with their axes radial, a novel form of telescope is proposed. This new form has properties that make it eminently suitable for X-ray astronomy, as with a 3 m hemisphere a survey of the sky to the limiting sensitivity of Uhuru would be performed in one hour. In a 2 year survey mission the whole sky could be surveyed to the limiting sensitivity of the deepest maps from the Einstein (HEAO 2) telescope.

In ref. [1] the two existing types of imaging, grazing-incidence telescopes currently used in X-ray astronomy are described.

Then the newly-discovered functioning of lobster-eyes is summarized (ref. [2]) and the application of this principle to telescope design discussed. A laboratory model with representative image for optical work is given, together with the predicted performance of two telescopes suitable for shuttle launch.

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T 22
HOW TO SURVIVE

By Geoffrey W. Wood and Karen R. Wood

Introduction

One of the authors recently posed the question of human survival and why we should be concerned with the outcome [1]. A few moments consideration of the frailty of the biosphere, the follies of human behaviour, the tremendous blind powers in the Universe of which astronomy is now making us more than ever aware [2], and the transience of other species, convinces us that there are many possible threats to humanity. Responses to them may take different forms. Ignore the threat hoping it will not materialize; attempt to control the threat at source; go somewhere other than the place that is threatened; attempt to control the effects of the threat in the immediate human environment rather than in the whole affected volume, and change humanity to some new form which is no longer threatened by the circumstances under consideration.

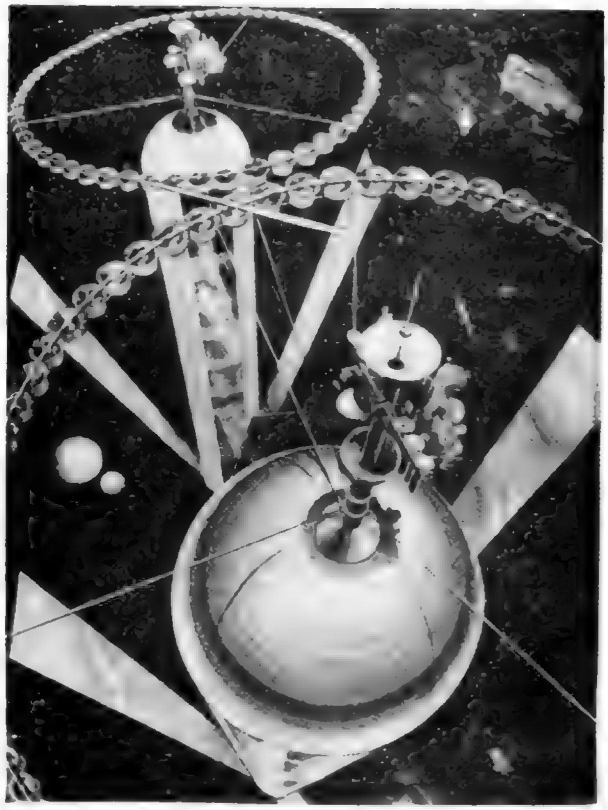
Responses to Threats

The first response, that of ignoring a threat, is practised by many individuals but it seems unlikely that humanity as a whole would be unanimous in this response were the threat sufficiently probable. There is a rational justification, however, for ignoring a threat in certain cases. It is possible to imagine threats which seem ludicrously improbable which it may be better to ignore than divert limited resources of time and materials to dealing with. Actions that might be taken in response to a more positive threat may be categorised as follows: stop it, run away from it, hide from it, and change oneself.

"Stop it"

The "stop it" approach seems at first sight to be most promising for dealing with threats that are internal in origin. All-out nuclear, chemical, or biological wars may have the capacity to destroy humanity in the near future, even if they are not thought to have it now [3]. Other suggested internal threats are the creation of a global thermal imbalance through increased atmospheric carbon dioxide; social breakdown [4] or a terminal experiment.

It seems beyond question that the most sensible actions would be to have nuclear disarmament and develop energy sources that do not increase the net carbon dioxide content of the atmosphere, if it is decided that the latter is definitely deleterious. How such results may be achieved in practice is another matter. Humanity consists of sovereign states and, within these, groups and individuals of varying degrees of independence. The fact that we can conveniently use one word for all of the people in the world may deceive us into considering them as one body, rather than as individuals lacking the homogeneity of desire or opinion necessary for concerted action. Having said that, there does remain the fact that we obviously have the physical power to stop something that we are doing, if we know it is threatening. That we may do something which we do not know is dangerous, such as carrying out a terminal experiment, is possible. The recent debate about genetic engineering, which was initiated by the researchers themselves, is reason for some optimism on this point, however. External threats are a different case in that most of them are beyond the physical power of humanity to control for the foreseeable future. Possible areas of human influence are the alteration of polar albedo to enhance ice cap melting or the use of rockets with nuclear warheads to divert or disperse planetesimals that threaten to intercept the Earth. Really large threats such as major variations in solar output seem at present quite beyond our power to control and for such cases other responses are required, such as the third one previously mentioned, running away.



O'Neill Space Colony, Model III, at Lagrange Point 5. Length 6.2 miles (10 km); diameter 1.24 miles (2 km). Population: 200,000 to 2 million people.

NASA

"Running Away" or "Hiding"

The "running away" option has been dealt with in detail by Michaud [5] and it is interesting to compare and contrast it with the fourth mentioned option, "hiding". The former would involve, depending on the nature of the threat and the volume affected by it, the colonization of near Earth space, other bodies in the Solar System, other solar systems and other galaxies. The latter would require the establishment on Earth of habitats which would be isolated to a greater or lesser degree from the environment, e.g. insulated against cold, shielded against radiation or biologically closed [6]. This last factor of closed biological cycles would, of course, be a requirement for prolonged spaceflight and colonization unless we were fortunate enough to come across a world sufficiently like our own to make this unnecessary. It would also be a requirement for all of the most extreme examples of hiding where the biosphere would have been destroyed. Certain disasters, such as biological warfare, may not require this degree of isolation from the environment and may permit, for instance, gaseous exchange between the isolated volume and the rest of the atmosphere, provided adequate filtration is used. Radiation shielding would be a requirement for all space travel and colonies in space though possibly not for all colonies on other bodies. On Earth it would be required to cope with the effects of nuclear warfare but not for, say, an ice age, where thermal insulation would suffice. Since warfare seems one of the more likely disasters in the near future on Earth, radiation shielding would probably be combined with blast protection by going underground.

How to Survive/contd

The similarities of the requirements for hiding on Earth and travelling in space are not surprising if one considers the two as both being cases of isolated habitats in hostile environments, i.e. the environment being hostile on Earth because otherwise one wouldn't be hiding and being hostile in space because it always will be for the present version of humanity. When it comes to colonizing other heavenly bodies the requirements may obviously be even more similar to those of hiding on Earth. The differences between the two approaches are also great, however. In terms of the disasters that could be survived, running away clearly has the edge, since hiding would be of no use against eventual solar expansion or some other cosmological catastrophe of sufficient magnitude to destroy the Earth. Since the former seems certain in the longest term then if one wished to survive it one would have to resort to running away at some stage.

In terms of cost and ease of achievement, hiding is at a great advantage since, although one may have requirements for habitats similar to those of space travel, one wouldn't have to lift such habitats out of a gravity well and project them across space. Hiding could therefore be achieved by relatively small groups and would not require whole superpowers to be committed to it, making it socially and politically far more feasible. Alternatively, for the same cost, far more people could hide than could flee. In terms of the quality of the environment there isn't much to choose between the two options, unless the previously mentioned Earthlike world should be happened upon.

Staying on Earth has the advantage of maintaining contact with a large and relatively well known resource base while space colonization may involve problems in this area, few bodies being known to have the mix of useful metals and major life elements as found on Earth. Space travel would be better in the case of an epidemic because of the tremendous time involved in travel across the vast distances of space. A subsonic jet can reach the other side of the Earth in a day and everyone could thus be exposed to an infection with little warning, or even before there was any warning at all. Colonies in other parts of the Solar System, on the other hand, or even farther afield, would have plenty of warning that something was amiss before any spacecraft carrying infection could reach them and they would have time to take appropriate action. Hiding on Earth may be less conspicuous to potentially hostile alien intelligences than space activities or it may be seen by them to be less of a threat if it is detected. It would, however, mean that were we to be found we would all be found, which may not be the case with widely dispersed colonies in space or on other bodies. Finally, psychologically speaking, space travel is probably preferable since it is extrovert, progressive and optimistic while hiding on Earth is introvert, stagnant and smacks of defeat.

"Changing Oneself"

The fifth response for consideration is that of changing oneself so that what was once a threat is a threat no longer. Humans could be changed phenotypically by hormonal alteration of physiology or by artificial electronic or mechanical additions or they could be changed genotypically either by selective breeding or possibly by genetic engineering. Things which may be of value for surviving possible disasters include increasing resistance to radiation by hormonally reducing cell division rates, decreasing the susceptibility of spermatogenesis to elevated ambient temperatures or altering metabolism to allow normal functioning at lower temperatures. There is probably a limit to what could be achieved by such tinkering with the present human form. Really large enhancements of survivability may only be achievable by replacement of the human physical form by some totally artificial self-maintaining and self-replicating intelligence. In this case the survival would be cultural, not genetic, but it would be a survival of organised effects as previously defined [1]. Artificial intelligences may be created which are able to survive temperatures near absolute zero or the vacuum of space, or capable of 'hibernating' for long periods with minimal energy consumption.

The latter four categories of response are not mutually incompatible, aside from their competition for resources of time, energy and materials. Indeed, they may be mutually assistive, such as if artificial intelligences indulged in interstellar travel, for which they may turn out to be better suited than humans, or if the information gained from the operation of earthbound closed cycles was applied in space, or vice versa.

The Credibility Factor

The greatest problem for survival may be that humans do not believe they are threatened. Not all disasters may give sufficient warning of their onset to allow responses to be decided upon and executed. Even if such warnings are received they may not be believed. "Gut" belief in a thing may depend on it being something one wants, whether there is any evidence for it or not, such as life after death, or, if the thing is unpleasant, on it having been experienced in one's lifetime. Evidence for the latter statement is provided by the number of people who don't believe they will have a serious road accident until it is too late. Major disasters are relatively infrequent in any human lifetime and even when they have happened, such as at Hiroshima, we seem to prefer to believe they will not happen again, or happen to us.

It would be wrong to be too gloomy about this because some of the courses of action which have, for the purpose of this article, been called responses to threats may come about for entirely different reasons. No space activity so far seems to have had survival as its aim, being instead either caused by curiosity, adventurousness, international competition or the desire to make long distance telephone calls or know what the weather will be like. Looking to the future, the colonization of space or the Moon has been put forward most seriously as a way of providing energy for Earth or of improving radio astronomy, not as a way of avoiding earthly disasters. Similarly, not many artificial intelligence researchers suggest that they aim to provide hardier offspring for the human race but seem, rather, to be trying to gain understanding of how we ourselves work or to give partial independence to interplanetary probes. Thus human survival may one day turn out to be a by-product of our curiosity or even of our competitiveness.

Conclusion

We should be prepared to believe in the possibility of extinction. It has, after all, happened before. An overwhelming proportion of the species that have ever existed on Earth have become extinct and it appears that they have not all become so simply because of replacement by fitter competitors. It is estimated that at the boundary between the Cretaceous and Tertiary periods fifty per cent of the genera then alive became extinct, possibly because of extraterrestrial influences [7]. We have the advantage over all of these creatures in that we possess imagination, reason and the ability to respond to our environment in ways never previously available to any species. It is to be hoped that complacency does not deny us the full benefit of these advantages.

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THE MUNICH CONGRESS

A REPORT OF THE PROCEEDINGS OF THE 30TH IAF CONGRESS

By Professor G. V. Groves* and Dr. L. R. Shepherd*

Introduction

The Deutsche Gesellschaft für Luft-und Raumfahrt, supported by the Hermann Oberth Society, acting as hosts to the 30th Congress of the IAF, chose Munich as the venue of the meeting; the third IAF Congress to be held in the Federal Republic of Germany. September is a month of special importance in Munich for its closing week is the time of the famous annual Oktoberfest. In the circumstances it was not surprising that the DGLR should have chosen the preceding week to hold the Congress feeling, no doubt, that many of the participants, after a gruelling week devoted to extra-terrestrial affairs might wish to abandon their cares in the ensuing festivities.

The Congress was based in the Deutsches Museum sited on an island in the River Isar (*Spaceflight*, May 1980, p. 208–209). The Museum has a Congress Centre which affords extensive facilities for large meetings, including an impressive Main Hall with its fine concert organ, as well as two well equipped lecture theatres and many smaller meeting rooms. Ample space was available in the Centre for the ancillary facilities of the Congress, such as the Registration and Information Offices, a Bank, Post Office, IAF Secretariat, Press Centre, Exhibits and for the many other activities that go to support such a large Conference.

Registration took place from noon on Sunday, 16 September and continued on succeeding days. The scale of the Congress can be judged from the fact that almost a thousand people attended the conference, the host country accounting for about one third of these (324). As usual, the foreign participation was dominated by the USA (245), with France (62), the UK (37) and USSR (26) also strongly represented. The USSR contingent included a high proportion of cosmonauts, among them Ivanchenko and Kovalyonok, who shared the 140 day long duration flight in Salyut 6. Only one US astronaut, Alan Bean, was present, a reflection of the extended pause in the American manned spaceflight activity.

The old part of Munich is now a pedestrian precinct and a pleasant place for a stroll. For the first day of the Ladies' Programme, a guided walk was arranged through the old town with visits to churches, monuments and other places of interest. The photograph is of the Marienplatz with the City Hall.

Congress Lecture Programme

It has become the custom to provide a theme for the IAF Congresses, that of Munich being "Space Development for the Future of Mankind". The theme does not indicate any limit to the scope of the meeting, since the technical papers presented at the conference cover the whole field of astronautics in a comprehensive manner and a fixed pattern of topics has gradually evolved, which continue to determine the sessions year after year.

At the Munich Congress there were 49 technical sessions including symposia of the International Academy of Astronautics and the International Institute of Space Law. Altogether, about 400 papers were presented in the course of the conference and it may be said that hardly any aspect of astronautics was not covered in these reports. The pattern of the technical sessions reflected an increasing tendency to divide the conference into a series of Symposia and Colloquia, each embracing a specific area of space technology or science.

The IAF as such divided its technical programme into three Symposia and twelve other sessions which were not collectively classified.

The main Symposia were: (i) Application Satellites; (ii) Manned Operations in Space; (iii) Space Transportation Systems.

The symposium on Application Satellites was sub-divided into Communications (4 sessions) and Earth & Ocean Observation (5 sessions). Manned Operations divided into the medical aspects (3 Bioastronautics sessions) and the engineering topics (4 sessions) with one session shared with the Academy of Astronautics, Space Rescue and Safety Symposium. Space Transportation Systems was made up by 6 sessions, 3 of which were concerned with present and future propulsion systems and their technology.

The independent technical sessions included ones on Materials and Structures; Space Power Systems; Scientific Spacecraft; Astrodynamics; Unmanned Solar System Exploration and Supervision of Youth Rocket Experiments, which has been an annual feature of the Congresses for very many years.

It would be difficult to find any area of astronautical science, engineering, medicine or sociology that is not covered in the IAF Congresses, either by the Federation itself or by its daughter organizations, the International Academy of Astronautics and the International Institute of Space Law. The Academy organized a Round Table on "Large Structures in Space" and a number of colloquia and symposia which have now become regular Congress features. These were the 8th Review on Communications with Extra-Terrestrial Intelligence (CETI); the 6th International Space Relativity Symposium; the 9th International Symposium on Space Economics and Benefits; the 13th History of Astronautics Symposium and the 12th International Space Rescue and Safety Symposium.

* *Past President, British Interplanetary Society.*

The Institute of Space Law devoted four sessions to its 22nd International Space Law Colloquium.

Inevitably, with 49 technical sessions spread over 5 morning and 4 afternoon periods, it was not possible for anyone to attend more than a small fraction of the Congress proceedings. It is, in fact, almost impossible for those participants who are officers of the Federation, Academy of Astronautics and Institute of Space Law, and official delegates to do more than attend a few of the lectures in any congress; since their time is otherwise taken up in attending plenary sessions, committee and working-party meetings. Frequent criticisms have been made of this situation by the many people who feel that the IAF Congress should provide the possibility for those attending to obtain a broad picture of the state of the art over the whole field of spaceflight. However, the view has prevailed that the IAF has to direct its Congress priorities to the specialist's requirements, if it is to ensure that a large number of participants are to obtain the necessary sponsorship to enable them to attend. This means that every conceivable subject has to be covered with a sufficient number of sessions to justify the specialist's journey. It is difficult to quarrel with this policy, but one cannot help feeling that some time should be reserved for a series of broad reviews which would enable Congress participants to obtain a general up-to-date picture of the state of the art.

An important factor contributing to the success of any technical conference, of course, is the availability of preprints of the lectures presented. The ability to study the text of any talk prior to its actual presentation greatly enhances the level of subsequent discussion of the paper. IAF Congresses over their thirty years, have not been outstanding in this respect often comparing unfavourably with many other large international conferences. The achievement of adequate preprint coverage, of course, depends upon the setting and adherence to deadlines sufficiently in advance of the actual meetings or otherwise by the participants' sponsoring organizations taking the responsibility for providing preprints. The Munich Congress had a relatively good preprint coverage of the technical programme, though it was apparent that there were many gaps. The organizers provided each participant with a book of Abstracts of Papers which included about half of the contributions. This useful book lost some of its value by virtue of the inadequacy of many of the abstracts. Detailed abstracts would be needed well in advance of the date of the Congress to eliminate such shortcomings. One problem with respect to the procurement of such detailed summaries and complete papers for the Congress, lies in the short lead time in the organization of the programme. The Programme Committee for any Congress is appointed at the preceding Congress, which implies that the time available from the date of calling for papers to the time when they should be in the hands of the session Chairmen for evaluation is at most about 6 months. This is scarcely adequate to ensure full preprint or detailed abstract coverage and in the circumstances the degree of success in this respect, that was achieved at Munich was creditable.

A feature of every Congress is the Opening Ceremony in which leading civic and governmental representatives are usually invited to address the Congress participants. A high note was struck in Munich, when, in response to the welcoming remarks by Professor Dr. Ing. Gerhard Brüning, President of the DGLR, Dr. h c Franz Josef Strauss, Prime Minister of the Free State of Bavaria and Hans-Hilger Haunschild, State Secretary in the Federal Ministry of Research and Technology, addressed a packed gathering in the Main Hall of the Congress Centre. Both speakers put special emphasis on the essential role of science and technology in ensuring a reasonable future for our children. If the anti-technology course, advocated by some, were to be followed the result would be catastrophic. Dr. Strauss pointed out that, far from being inimical to mankind, science, technology and industry provided the only means of solving the formidable problems that lay ahead. State Secretary Hans-Hilger Haunschild said that despite the slowing down, in recent years, of space activities due to preoccupation with many other important problems, developments must continue in the space field and he stressed the determination of the Federal authorities in his country to continue their support in this direction.

The Lord Mayor of Munich, Erich Kiesl, and the General Director of the German Museum, gave addresses welcoming the Congressists and IAF President, Roy Gibson, replied on behalf of the Federation to these distinguished speakers. The opening proceedings were wound up with an organ recital by Professor Müller-Bechtel.

Following the Opening Ceremony the 10th IAF Invited Lecture was presented. This was a talk on the Congress theme, "Space Development for the Future of Mankind", prepared by Christopher C. Kraft Jr., of NASA. In the absence of the

A half-day free excursion was arranged for participants at the mid-stage of the Congress by coach and boat to the famous Herrenchiemsee Castle built in 1873 by the Bavarian King Ludwig II. The building and grounds are modelled on the Palace of Versailles.

author, who was unavoidably detained in the USA by urgent work on the Space Shuttle, the paper was presented by Alan Bean.

The IAF General Assembly

The International Astronautical Congress serves two main purposes; the one being that of an international conference at which scientific and technical papers are presented; the other being the annual meeting of representatives of the constituent societies of the IAF, in plenary session, to discuss the business of the Federation, particularly questions of finance, membership, relations with other relevant international organizations and its various activities in the furtherance of astronautical developments. The plenary sessions are supplemented by the meetings of various committees and working parties and of the Bureau which, made up of the elected officers of the IAF, acts as its executive and general purposes committee. It may be noted that the Bureau, in addition to its meetings in the Congress, also meets annually in late March or early April at the IAF's Paris headquarters.

In addition to the Federation's own business meetings the Academy of Astronautics and International Institute of Space Law, hold their own plenary sessions and their respective directors serve, ex-officio, on the IAF Bureau.

The General Assembly of the IAF, is made up by the delegates from the various voting and non-voting societies. This is arranged on a national basis, each country having one voting member society, but any number of non-voting members which might happen to qualify. In the case of the UK, the BIS is the voting member while the Royal Aeronautical Society Guided Flight Section is the non-voting member. In the discussions in plenary session all delegates, whether of voting or non-voting members, have equal right of speech, but only the voting societies delegates have the right to cast a vote.

The delegates at Munich, in accordance with custom, met in two plenary sessions on Monday and Friday. Of the IAF's 37 member countries, representatives from 30 were present for the roll call at the opening session. The agenda presented three particularly difficult matters on two of which decisions and actions could not be long delayed. These were the parlous state of the IAF's finances and the choice of venue for the 1981 Congress between Stockholm and Rome, with both Sweden and Italy as eager suitors. The third matter concerned the status that could be given to the Astronautical Society of mainland China when full voting rights were already held by that of off-shore China (Taiwan). Thanks to the skilful guidance of the President, Mr. Roy Gibson, the Assembly proceeded to move smoothly through the Agenda by taking the opportunity of the first session to outline the nature of these problems and to defer any decisions to the second session.

Some light relief came to the first session when a design for an IAF seal was presented to the meeting for approval subject to sizes of certain lettering being changed to give greater prominence to the inscription "IAF". Comments on the design from the floor were generally unfavourable, but it was agreed that the General Assembly was not the best place to start a new design. As much time and effort had already been expended on the present design it was decided that any seal was better than none and the resolution was adopted.

The frequency of future Congresses being either annual or biennial was dealt with by approving the following resolution:

"The General Assembly has been informed that COSPAR intends in future to organize its congresses every second year. In order to evaluate the possibility of the IAF holding its main Congress in alternate years, the Bureau should appoint a small group to discuss the subject in depth with COSPAR and with ICAS and to present a proposal, covering all aspects, in time for a decision to be taken at the General Assembly in Tokyo in 1980"

The dates of the Tokyo Congress were announced as 21/28 September 1980 and the theme of the meeting will be "Applications of Space Developments". Plans included 45 sessions and an Invited Lecture on "Economic Effects of Space Developments" by Andre Lebeau, Deputy Director of ESA. In line with the general streamlining of IAF committees, the International Programme Committee would be reduced in numbers and include three Symposium Co-ordinators. Unfortunately, no list of session chairmen for the 1980 Congress was announced and firm information on administrative procedures for expediting the submission and acceptance of papers from intending authors was not forthcoming.* Three symposia for the 1980 Congress were announced, being in the areas of: (i) Space & Energy; (ii) Earth-Oriented Research; (iii) Low-Gravity Research.

The intended dissolution of SYRE (Supervision of Youth Rocket Experiments) Study Group was staved off by a vigorous campaign of lobbying delegates. SYRE will continue as a sub-committee of the Education Committee under the chairmanship of Dr. G. S. James.

The tricky problem of the status of the Astronautical Society of mainland China was the subject of a resolution (unanimously carried) expressing the difficulty that the IAF would face in modifying the status of a society which was complying with the Constitution, ie Taiwan, and asking the President to discuss the matter with the mainland society in the light of the recent example of the IAU's approach to the same problem.

Authority was given to the Bureau to decide the choice of the 1981 venue as neither Sweden nor Italy was yet in a position to make a 100 per cent firm offer.

To check the decline in the financial status of the IAF, the Finance Committee of the Bureau proposed that extra income should be sought from member societies and from other existing sources such as institutional members, IAF registration fees, and the preparation of reports for UN and other agencies. The proposed 50 per cent increase for member societies met with support from some smaller societies but not from the larger ones for whom the extra costs could not be recovered from their members' subscriptions as these had already been fixed for 1980. The President said that the proposals would not be put to the Assembly for formal adoption as he would first like to write to member societies to ask for donations and explain the need for a 50 per cent increase. It was also proposed that payment dates should be brought forward to 28 February 1980, with interest added for late payments. For subsequent years annual increases were proposed at the going rate of inflation.

Appointments to IAF Committees and Working Groups were approved as follows:

Bioastronautics Committee:	H. von Beckh (USA) to succeed D. L. Winters as Chairman, Professor E. Lauscher (FRG) appointed.
Education Committee:	R. Kling (France), P. J. Conchie (UK), G. J. N. Smith (UK) appointed and one USSR member to be nominated.
Committee on Space Applications:	Yu. V. Zonov (USSR) as Co-Chairman.
Working Group on Space & Energy:	R. Akiba (Japan) appointed.
Committee for Promotion of Activities and Membership:	R. Monti to succeed M. Barrere as Chairman.
Publications Committee:	G. G. Chernyi (USSR) appointed.

* *This information was subsequently circulated to Member Societies and other interested bodies in December 1979.*

CORRESPONDENCE

"High Road to the Moon"

Sir, I have just received my copy of *High Road to the Moon*. Thank you Bob Parkinson for a thoughtful and sensitive analysis of one of the driving forces behind Apollo. Looking at R. A. Smith's pictures, one can see how many of our "new" ideas were proposed a generation ago by the early BIS. Let us hope that we will do justice to the pioneers by developing their proposals far enough to convince even the powers that be. The technology of lunar colonization is waiting to be assembled and exploited. Despite the present political climate, we can show what should be done, on paper at least.

DR. D. J. SHEPPARD,
Allesley Park,
Coventry.

Space Shuttle delays

Sir, The regular announcements from NASA of yet another postponement of the launch of the first Shuttle Orbiter (now the end of 1980!) is beginning to dishearten me. It reminds me of the well known proverbial donkey and the carrot or better still the pot of gold at the end of the rainbow.

Although startling information has been sent back from deep space probes it's still not as exciting as manned spaceflight and I am beginning to lose interest in space development. Many of the people I speak to think the Americans have abandoned their manned space programme and the latest news that the USA is putting a satellite aboard the ESA Ariane confirms they too are losing faith.

PETER B. JONES,
Abertillery,
Gwent.

The Editor writes:
Delays in launching the Space Shuttle "Columbia" at Cape Canaveral reflect both technical and financial considerations. It must be recognized that the Shuttle is a project of high technology and restrictions on the space budget by President Carter and the Congress have made NASA's problems particularly difficult. No one, least of all the space officials concerned, would wish to cut corners and risk human life in the process. The delay in bringing the Shuttle to the pad does, however, give Europe a golden opportunity to break into the world market for satellite launching with Ariane which made a successful maiden flight from Kourou, French Guiana, on 24 December 1979.

Astronaut Selection

Sir, I have just read David Shayler's Space Report item "NASA calls for Group 9 Astronauts" (*Spaceflight*, 1980, pp. 39–40) in which he writes: "The latest group of 35 astronauts selected in January, 1978 are well advanced with their two-year training programme, which is due to be completed in July, 1980."

In fact, NASA announced on 31 August 1979 [1,2] that the 35 had completed their training and were now eligible for selection as Space Shuttle crew members. The original two-year training programme had been cut in half. George W. Abbey, Director of Flight Operations at the Johnson Space Center, commented: "We are pleased with the newest group of astronauts' performance and their adaptation to the Space Shuttle programme" and added that the Astronaut Corps now numbers 62, men and women, and that future astronaut candidate training will also be held to one year.

I am certain that it will also be of interest to readers of the article "Return to Apollo" (*Spaceflight* 1980, pp. 7–21) that four man-made islands in San Pedro Bay, California, christened in 1967 in honour of four dead American astronauts by officials of the City of Long Beach, have recently been officially named by the US Geological Survey as Island Chaffee, Island Freeman, Island Grissom, and Island White.

PHILIP W. SNOWDON,
Bromley,
Kent.

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Cosmos 929

In linking the reported failure of a Proton launch vehicle on 4 August 1977 with Cosmos 929, Nicholas Johnson [1] has fallen into the trap of drawing a conclusion from too little information. There is more to an orbit than apogee, perigee and inclination. When two spacecraft are required to rendezvous without unnecessarily high fuel expenditure, they must both be orbiting in the same plane and in such a way that at the desired time they are at roughly the same location in space.

For example, manned Soyuz flights to Salyut space stations require the Soyuz orbit to be in the same plane as that of Salyut. After the normal Soyuz systems check, the initial low orbit is changed to one with its apogee at the same height as Salyut's circular orbit. Choice of a suitable separation between the two craft at launch ensures that when Soyuz is at apogee on rev 17, it is close to Salyut. A firing of the Soyuz engine ensures that it enters the circular orbit alongside Salyut. It was the failure of this last manoeuvre to be completed by Soyuz 33 that forced cancellation of its docking with Salyut 6, each successive return to apogee of the Soyuz increased the separation between the two vehicles by about 120 km.

A similar flight profile would be followed by an object launched to rendezvous with Cosmos 929, launch of the second vehicle occurring as the plane of the target's orbit passed Tyuratam, due to the rotation of the Earth.

On 4 August, Cosmos 929 itself was still in a relatively low orbit so very little separation would be required between it and a chasing vehicle. Launch for rendezvous therefore would take place on an orbit when Cosmos 929 crossed the equator, northbound, at a longitude of approximately 346 degrees west. (In the case of Salyut in a 91.4 minute orbit, the Soyuz launch takes place when Salyut's equator crossing is about 341 degrees west, the orbit plane passes Tyuratam about 25 minutes later when the Soyuz lifts off. The difference in time between Soyuz and Salyut is then reduced over the next 24 hours by virtue of Soyuz' lower orbit).

The following are equator crossing times and longitudes for Cosmos 929 on the three days centred on 4 August 1977:

Date	Rev	Time UT	Longitude (deg w)
3 Aug	270	0217	357
4 Aug	285	0034	338
5 Aug	301	0020	341

If a rendezvous had been attempted about 4 August, the best date would have been 7 August in the very early hours of the morning (UT). Cosmos 929 crossed the equator at 346 degrees west at 2351 UT on 6 August, and lift off of a second craft would have occurred a few minutes after midnight.

I think Nicholas Johnson is also wrong to try and connect Cosmos 929 directly with Salyut 6. The probe and drogue mechanism, along with a set of peripheral latches may well be suitable for holding a 6½ tonne Soyuz and a 19 tonne Salyut together but I submit that something stronger would be needed to deal with the inertia of two Salyut-sized objects. There may

well be a necessity for permanent, welded or bolted connections between them, with the usual latch system operating around the transfer hatches to ensure the sealing.

Soviet controllers were themselves concerned about the linking of another Soyuz to the combined Soyuz/Salyut unit of 25 tonnes mass, hence the "Resonance" experiments aboard Salyut 6; and the fact that Romanenko and Grechko retreated to Soyuz 26 during the docking with Soyuz 27 in case the existing connection was broken by unforeseen forces.

As I have already pointed out [2], there exists a relationship between the flights of Cosmos 1074 and Cosmos 1001, and Cosmos 929. The mid-August manoeuvre of Cosmos 929 produced an orbit with a period of 90.75 minutes which was almost exactly mirrored by the other two during their own manoeuvres:

Date	Cosmos	Perigee (km)	Apogee (km)	Argument of perigee (deg)
19 Aug '77	929	312	318	280
11 Apr '78	10001	309	319	299
3 Feb '79	1074	309	321	303

I agree with the analysis of these flights as elements of a programme leading to the construction of units larger than Salyut, but I do not feel that such a feat was planned for 1977. Cosmos 929, Cosmos 1001 and Cosmos 1074 may all represent steps along the road. If Cosmos 929 was the failure suggested by Nicholas Johnson I think we would have seen the attempt repeated before now.

ROBERT D. CHRISTY,
Lincoln, England.

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1. Johnson, Nicholas L. "The Prospect of Soviet Orbital Construction in the Summer of 1977", *Spaceflight*, December 1979, p 518.
2. Christy, Robert D, "Orbits of Soviet Spacecraft at 51.6° inclination", *Spaceflight*, February 1980.

BOOK REVIEW

Lifecloud – the Origin of Life in the Universe.
By Fred Hoyle and N. C. Wickramasinghe, J. M. Dent, 1978, £5.95

This book is quoted in the publisher's blurb as "one of the most important astronomy books . . . for many years". Be that as it may, it is certainly a remarkable inter-disciplinary presentation of Hoyle and Wickramasinghe's theory that life did not originate, as presently assumed, in some thunder-struck primaeval soup, but from the far reaches of interstellar space, in the bellies of comets, later to literally rain down upon a previously sterile Earth. They also suggest, more or less as an aside, that *all* the volatiles making up Earth's oceans and atmosphere came to it (shades of Velikovsky) in a similar fashion.

The idea of life having arisen in space is not so new or surprising, especially when one considers the number of organic molecules that have now been detected in interstellar clouds. Where this book is interesting and new is in the way it presents its view from so many approaches – astronomical, biological, chemical, and (unfortunately) philosophical. The latter is one area where it falls down, since its "philosophical" speculations and historical asides are sometimes simplified to the point of crassness. A whole chapter is devoted to the authors' ideas on the predator/prey relationship driving evolution, which, on their own, are almost truistic, and which when later expanded in a discussion on interstellar life have been far better handled elsewhere (including the pages of our own *JBIS*). BIS members might do as well to skip the last few chapters on the possibilities of interstellar travel and communication since they say little that is new, and in their superficial quantitative analyses disguise the sort of prejudgement of issues the authors accuse the "primal soup" theorists of.

This philosophical failing is perhaps the result of an attempt to keep the general level of the arguments to layman's terms. They give, for instance, basic atomic theory and an overview of the Solar System, suggesting they expect their audience not to have had even a basic science training. Some popularisation is necessary in a book covering so many disciplines, but it does leave the impression of superficiality. This reviewer would like to think that all the general statements made could be backed up by some in-depth work in some areas. If so, it will be interesting to see how the theory holds up under test. Certainly, it seems to have led to further work by the authors themselves since Hoyle presented some additions to the theory on BBC Radio where he suggested that sudden occurrences of diseases apparently simultaneously at sites thousands of kilometres apart could be the result of new organic material still arriving from space. This sort of thing is hinted at in the book when the claim is made that Darwinian evolution is too slow to account for some of the sudden increases in number of species, such as after the Cretaceous.

The authors seem prepared for strong criticism from the scientific establishment, to the extent of "lashing out" in what seems preparatory self-defence in one or two places. They criticise the "primal soup" theory as replacing "the religious mysteries which surrounded this question with equally mysterious scientific dogmas". A bit strong when that theory is not that far different from theirs in the theoretical problems it has to overcome, and where both start from essentially similar components. There is also a quite cogent argument that there are shortcomings in Whipple's icy conglomerates model for comets. Yet the authors do not give us, at least in this text, a detailed description of their alternative. That is especially surprising since it is in the warm (oh, yes!) interiors of comets that their own organic stew is brewing. It would be nice to have a better explanation for the mechanism that warms the comets' insides enough for the chemical evolutions needed. There is a hint at warmings when they pass close to the Sun, but the vast majority of comets spend all their lives in the cold of interstellar space?

For all its flaws, and the authors themselves in places admit to problems, it is a book to revive speculation in areas too long taken for granted. It is, in short, fascinating reading. It is at its best when asking those "awkward" questions on contemporary assumptions: Where was the Earth supposed to have got the reducing atmosphere necessary for the early generation of organics when all the evidence (see, eg, Venus and Mars now) is that it would have had an oxidising one? Can all the necessary components for life have come from that same reducing mixture? Where, indeed, did the rocky, dense, inner planets get any atmosphere at all from?

Questions to get one thinking indeed!

ALAN FARMER

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 NOS 7–8 JULY–AUGUST 1980 *Published 15 June 1980*

Editor:
Kenneth W. Gatland, FRAS, FBIS

CONTENTS

COVER

SALYUT 6 RE-MANNED. Soviet cosmonauts are pressing ahead with new experiments aboard the Salyut 6 space station, and remarkably one of them is the veteran design engineer Valery Ryumin who (according to a report from Moscow) replaced Valentin Lebedev who damaged his knee during training. Ryumin was originally instructing his colleagues on tasks to be performed after they boarded the station and volunteered to go instead; he had only returned from Salyut 6 last August after a record-breaking 175 days in space. *Top left*, pre-flight photo of Soyuz 35 cosmonauts Lt.-Col. Leonid Popov and Valery Ryumin who docked with the Salyut 6/Progress 8 complex on 10 April 1980. *Right*, after a training session in their space suits. *Below*, Salyut 6/Soyuz 31 complex as photographed in flight by cosmonaut Sigmund Jähn of the German Democratic Republic.

Top and right, Novosti Press Agency; Bottom, Theo Pirard.

Owing to the trade agreement giving employees of the printing industry four weeks annual holiday, this is a combined issue covering the months of July and August. The next issue of 'Spaceflight' will be published during the third week of August, as usual.

MILESTONES

April 1980

12 *Tass* reports that Progress 8, docked to Salyut 6, was used to raise the orbit of the space station complex prior to the arrival of the Soyuz 35 cosmonauts.

14 NASA announces that it is studying options "to re-structure Landsat-D project because of increasing engineering and managerial problems encountered in the manufacture of the spacecraft's instruments and general systems." Difficulties have been encountered by Hughes Aircraft Company in building an advanced scanning device called the thermic mapper which should define Earth imagery in more spectral bands and with twice the resolution (30 metres) of multispectral scanners of earlier Landsats. Also, mission system coordinator, General Electric Company, is experiencing problems and delays resulting in greater than anticipated costs for development of both Landsat-D and ground systems.

14 A Space Shuttle main engine is successfully tested at 109% of rated power in the second such test in two weeks at NASA's National Space Technology Laboratories, Bay St. Louis. The test was the second successful sustained.

16 A planned 10-minute test of the Space Shuttle's main engine cluster is terminated automatically after about six minutes at NASA's National Space Technology Laboratories, Bay St. Louis, Mississippi. Probable cause of the shutdown is identified as a discharge overtemperature on the high pressure fuel tubopump of engine no. 2 of the three-engine cluster. There was no apparent damage to the engines or the test stand.

18 Soviets launch Cosmos 1174, a satellite interceptor, by F-1 vehicle from Tyuratam-Baikonur at approximately 0040 UT. Over the next two orbits, Cosmos 1174 "chases" Cosmos 1171 and intercepts it shortly after 0400 UT about 1,000 km above East Germany. Several objects which appeared after the interception were still in orbit at the end of the month. Cosmos 1171 was launched from Plesetsk into a 966 × 1009 km, 65.84 deg orbit on 3 April, using a C-1 vehicle. On 27 March, Cosmos 1169, also launched from Plesetsk, entered a 476 × 515 km, 65.84 deg orbit to act as a radar calibration target, heralding the next test of a satellite interception system. RDC.

19 Static test of a Space Shuttle Main Engine at the National Space Technology Laboratories, Bay St. Louis, is described as "highly successful". It ended series of tests with simulated power levels necessary for an "abort to orbit" during a Shuttle launch.

23 NASA issues $70,072,000 follow-on fixed price incentive contract to McDonnell Douglas Astronautics Company for Delta expendable launch vehicle services. Contract calls for continuation for two years of launch services work performed by the company for the past 19 years for Delta including mission peculiar vehicle changes, checkout and launch.

25 Progress 8 is undocked from Salyut 6 for disposal over the Central Pacific.

27 Soviets launch Progress 9 from Tyuratam-Baikonur at 09.24 hr (Moscow time) to carry additional supplies to the two cosmonauts aboard Salyut 6. Initial orbit 119 × 171 miles (192 × 257 km) × 51.6 deg.

29 Soviets launch Cosmos 1176 from Tyuratam-Baikonur into orbit of 162 × 165 miles (260 × 265 km) × 65 deg; believed to be a radar ocean surveillance satellite of the kind previously powered by a nuclear reactor (as Cosmos 954 which disintegrated over Northern Canada in 1978).

May 1980

1 NASA announces that the three Space Shuttle Main Engines designated for the maiden flight of the Orbiter "Columbia" will be re-tested to assure operational readiness. Decision follows a number of modifications made during the past year

[*Continued on page 276*

PROJECT BOMI

By Curtis Peebles

Introduction

In the decade after the end of World War II, there were numerous proposals for winged rockets both sub-orbital and orbital. One of these studies was made at Bell Aircraft Company during the early 1950's. Like the other proposals, it was technologically and politically ahead of its time and so never flew. The study was conducted in secret and very little was made public after its abandonment, which is ironic since it was the first to embody the features of the modern totally reusable Space Shuttle and it set events in motion that made it the direct predecessor of the US Space Shuttle.

Origins of Bomi

In 1951, Dr. Walter Dornberger, former commandant at Peenemünde, was a consultant at Bell Aircraft. He suggested to the US Air Force a long-range rocket bomber as an alternative to the guided missile at a time when missile accuracy over long ranges was more limited and lack of recall capability was considered a significant shortcoming of non-piloted bombardment systems.

The vehicle was a composite (two winged craft, one on the back of the other). The German Air Force had developed a composite weapon late in World War II, the Mistel (Mistletoe) - an Me 109 or FW 190 fighter atop an unmanned Ju 88 bomber with a 7716 lb (3500 kg) armour piercing warhead. With a composite design, one avoided the aerodynamic, structural and design problems of putting two winged vehicles into the normal missile configuration.

Another technological predecessor, although perhaps a less direct one because of its completely different approach, was the Antipodal bomber. This was a single-stage track-launched vehicle able to fly from Germany to Japan using a skip glide flight path. Dr. Eugene Sanger, who had developed the concept, was asked by Dr. Dornberger to join the Bell team but he refused, preferring to remain in France. In 1952, Dr. Dornberger invited Dr. Krafft Ehricke, then Chief of the Gasdynamics Section at the Army Ballistic Missile Agency in Huntsville, Alabama, who accepted.

The Bomi Vehicle

The Bombi, which stood for BOmber MIssile, represented a family of two stage study vehicles with varying capabilities. One had a 4,000 mile (6436 km) range; another had a 6,000 mile (9654 km) range and another's upper stage had the ability to U-turn and fly back to the launch site. The basic configuration was a two-stage, sub-orbital rocket aircraft which was launched vertically like a conventional missile - a larger lower stage carrying a smaller upper stage; both manned. After separation, the lower stage would fly back to a landing while the upper stage flew on. Both stages would land on conventional run-ways.

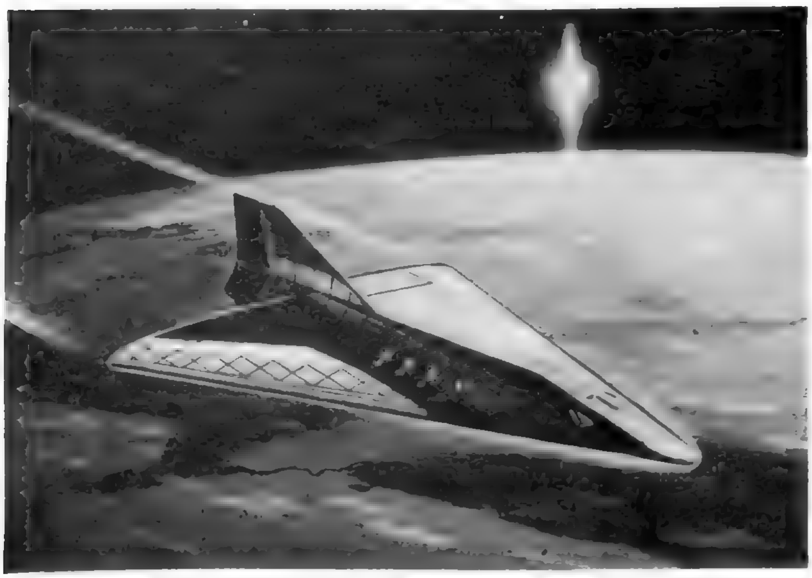
Dr. Ehricke found that any glide return capability would seriously compromise many other desirable mission qualities, because of unfavourable aerodynamic conditions involved at the high speeds envisaged. Recognizing that the launch velocities involved amounted to 75 per cent or more of the velocity needed to become orbital, he proposed a single - or multiple orbit version of Bomi, which would provide a return capability to the launch area or the continental United States. For the sub-orbital versions, Dr. Ehricke compared the steady glide mode with a skip glide flight path such as was projected for the Antipodal Bomber, and recommended the steady glide mode.

The lower stage was 100 to 120 ft (30.5 to 36.6 m) in length with a wing span of 60 ft (18.3 m). Most of the structure was aluminium with titanium leading edges and nose for high temperatures. The sub-orbital version had a gross lift-off weight of approximately 600,000 to 800,000 lb (272,160 to 362,880 kg) for the two stages.

The propellants considered were all-storable (UDMH and nitrogen tetroxide) and partially storable (jet fuel and liquid oxygen).

The 5-engine version of the lower stage had a thrust of 770,000 lb (349,272 kg). The lower stage carried a crew of two.

The upper stage dimensions, for the sub-orbital version, were highly dependent on the mission but generally speaking were 50 to 60 ft (15.2 to 18.3 m) long and 30 to 40 ft (9.14 to 12.19 m) wing span. It was built entirely of titanium and used radiant cooling. It had three engines with a total thrust of 110,000 to 139,000 lb (49,896 to 63,050 kg), used the same propellants and had a fuelled weight of approximately 200,000 lb (90,720 kg). Both stages ignited at lift-off. The upper stage carried a crew of one.



SHUTTLE OF THE 'FIFTIES. An early configuration of the Bomi upper stage. The tile-like features, on this artist's conception, are noteworthy.

Bell Aerospace Textron

The payload was small – about 4000 lbs (1814 kg). This included a single nuclear bomb and the release mechanism. The bomb bay was in the vehicle's underside and was covered by rollaway doors. The bomb had a rocket separation system and there was a command link between the pilot and the bomb allowing more precise aiming. Release altitude was between 100,000 to 200,000 ft. (30,480 to 60,960 m).

The Bomi was to be based overseas in England, Spain, Africa and Canada. Potential target areas specified included military targets in western Russia. The Siberian part of Russia was too sparsley developed to warrant use of such a system. A typical mission would involve a launch from England, a long glide over Russia and a landing of the upper stage at a base in Africa. The bases would have the launch pads, support equipment and runways for recovery of the stages. The basing of such a system in foreign countries sounds strange today but in the early 1950's, the US Strategic Air Command had numerous forward bases in these area. At that time, they were out of range of Soviet air strikes and naval forces.

The Bomi had several advantages – conventional anti-aircraft was powerless to stop it. It was much faster and flew higher than an aircraft. Unlike a missile, it could be recalled after launch. Because it had a crew, human judgement could be applied. Targeting information could be updated after launch. Also, a target, whose exact location was uncertain, could be visually located. The upper stage, also, could be equipped for reconnaissance missions.

Dr. Dornberger and Dr. Ehricke were, also, unofficially studying Bomi's civilian usefulness for high-speed global air travel, extending the use of this rocket transport from a nuclear delivery system into a far wider frontier.* Dr. Ehricke, also, hoped his orbital version would become the reusable space transport needed to put space activities on a far more cost-effective basis.

Orbit Bomi

The final velocity of the highest performance version of Bomi was roughly 26,000 ft/sec (7924 m/sec). Dr. Ehricke realized that the addition of some 5000 ft/sec (1524 m/sec) would put the upper stage into orbit. This meant, using storable propellants, roughly a 20 per cent increase in the vehicle. The vehicle dimensions, of the lower stage, were increased to 120 to 144 ft (36.6 to 43.9 m). For 14,000 lb (6350 kg) payload weight, the launch weight was increased to some 940,000 lb (426,384 kg). Lift-off thrust was increased to almost 1.1 million lb (498,960 kg).

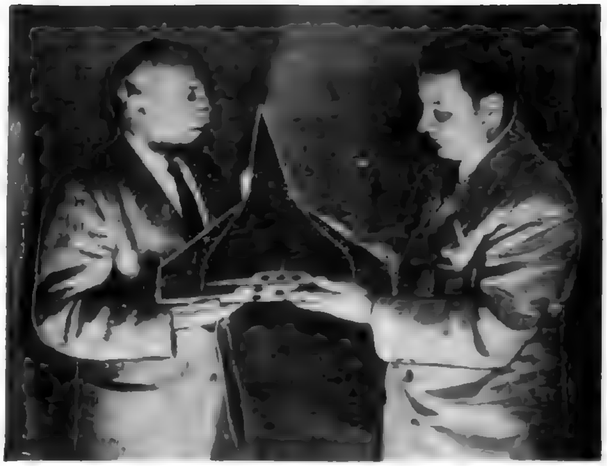
The lower stage was now built entirely of titanium to cope with the higher temperatures. The upper stage was increased in size by about 25 per cent to roughly 62 to 75 ft (18.8 to 22.9 m) long. It was entirely covered with a graphite epoxy ablative heat shield on a honeycomb backing. It was hoped that the graphite epoxy could be sprayed on, after a mission, to renew the heat shield. This was one of the unknowns in vehicle development.

The system requirements were more stringent in all areas. It was assumed that it would have a stay time of several orbits; thus it could be based in the United States.

There was considerable discussion with the Air Force over the crew. The Air Force felt that one pilot may not be enough to cope with the increased workload of such a prolonged mission – a two man crew, therefore, might be necessary. It was never settled as to whether the crew would be one or two men.

The upper stage had 4 or 5 engines equipped with new nozzles for a better expansion ratio. Thrust was 220,000 lb (in vacuo) (99,792 kg) total. The payload was increased to 12,000 to 14,000 lb (5443 to 6350 kg).

* *The launch profile of this version was detailed in the November 1979 issue of "Spaceflight".*



Dr. Walter Dornberger (left) and Dr. Krafft Ehricke hold a model of a civilian version of Bomi for high-speed global air travel. The design is amazingly similar to those of the Space Shuttles proposed in the late 1960's and 70's.

Photo courtesy Krafft Ehricke

Two nuclear bombs were carried. Part of the payload increase was due to the stringent heating requirements of the bombs. Dr. Ehricke rejected the idea of a conventional bomb bay in the underside of the vehicle. Any problem in sealing the bay or a door jamming open would destroy the vehicle during re-entry. This was solved by a novel arrangement in the 5-engine version. At the rear of the vehicle, one main engine was placed in the centre; two engines were placed on either side of the centre engine. Above and below the centre engine, were the cylindrical bomb bays. The bombs were ejected backwards. There was no thought given to a bay in the top of the upper stage.

Dr. Ehricke further developed the idea of Orbit Bomi by changing the propellant to liquid oxygen and liquid hydrogen. This resulted in considerable changes in the vehicle due to the low density of liquid hydrogen. The lower stage became twice as long. The upper stage was increased in size by 50 per cent making the two more equal in size but paradoxically the weight did not increase proportionally. A liquid hydrogen fuelled upper stage weighed one third less than a storable fuelled upper stage; a tremendous advantage. Yet, despite this, little interest was shown in liquid hydrogen. The sheer size of the lower stage frightened the Air Force. Also, liquid hydrogen was then little more than a laboratory curiosity. Also, if the Bomi was fuelled with storable propellants, it could be launched quickly, something not possible with propellants like liquid oxygen or liquid hydrogen.

Development Plans

When Dr. Dornberger presented his study to the Air Force, it included a tentative development plan. One of the selling points was that Bomi represented a family of concepts so that if one of the sub-orbital versions was developed, an orbital capacity could be achieved without a completely new development programme. It would be a stretched version of the sub-orbital Bomi rather than a completely new vehicle. The Air Force considered the 6000 mile (9654 km) range version to be the reference. The orbital version was considered to be a derivative.

Had the vehicle been approved in 1954, development would have begun with extensive studies of the many engineering unknowns. The design would be further refined and developed. The actual building of the vehicle and flight testing would not be until 1959–1960. This would last until 1965. Flight testing would begin with ground static testing firings. The lower stage

would be flown by a single test pilot as steadily increasing speeds working from low speeds up to those that it would achieve at upper stage separation. Then the upper stage would be carried, at first empty and then it too would go through a similar speed build-up until a full flight profile was made. This goal could be achieved quickly with a minimum of test flights. There were to be no unmanned flights partially because automatic equipment did not then have the capacity and, also, because the vehicle was considered to be a rocket aircraft and any risks associated with the flight of such a vehicle would be mimimized by the presence of a test pilot. Unlike a ballistic missile programme, which involved the construction of numerous test vehicles, only two sets of Bomi test vehicles were planned; one set as the prime test article and one back-up set. After the performance testing was concluded, a two year programme of operational test flights was planned. These would include testing the bombing systems, reconnaissance systems and various special mission manoeuvres.

One of the areas of discussion with the Air Force dealt with the accuracy it could achieve. The bomb flew in a very shallow trajectory. Also, the command link could be jammed. The area of thermal protection was another problem that Bell and the Air Force spent much time thrashing out. A reusable orbital transport could have become operational at or before 1975, depending on programme priority.

Bomi's Legacy

The project lasted from 1951 to late 1954-early 1955. The end came for a number of reasons. With Bell management, it was the realization that the Company was too small to undertake the project. Even if Government had accepted the project, it would have been built by another company such as Boeing, Convair or North American Aviation. It was decided that Bell would concentrate on helicopter production.

The Air Force lost interest in the sub-orbital Bomi due to the decision to concentrate on the ICBM. The ICBM was simpler and cheaper, and if it was less flexible, it had the undeniable advantage of being ready much sooner.

The Orbit Bomi continued to be studied by the Air Force at Wright-Patterson Air Force Base. Interest continued for two reasons. First, because it had a recall capability. At that time, many in the Air Force disliked the finality of an ICBM launch. An unspoken, and probably more important reason, was an interest by the Air Force in having its own space programme. An Orbit Bomi, being fully reusable, would be a first step in that direction leading to the establishment of a space station – another of the Air Force space enthusiasts' goals.

By 1955, the Air Force had terminated the Bomi effort but interest in winged rockets continued. In the coming years, the Air Force would issue study contracts on related subjects. These would lead to the X-20 Dyna-Soar. This, in turn, would give way to the lifting bodies and then, in turn, to the Space Shuttle.

Acknowledgements

I wish to express my sincere thanks to Dr. Krafft A. Ehricke. Without his help, this article would never have been written.

LESSONS OF APOLLO

Dr. George M. Low recently addressed the annual meeting of the National Academy of Engineering. Low is the former Apollo spacecraft project manager and presently the president of Renaselaer Polytechnic Institute, writes Gerald L. Borrowman. Dr. Low suggested that the nuclear power industry could learn some lessons from the space programme on the running of high technology systems safely and effectively. He went on to suggest that the nuclear industry add management people with space programme experience.

After reading the report by President Carter's commission on the Three Mile Island Accident, Low said he is convinced that many lessons learned in the Apollo programme could be applied directly to nuclear power plants. These include the importance of standardizing designs and rigorously testing components having a clear-cut chain of command for management responsibilities, having the actual operators involved in every stage of designing equipment, and hiring and training of the best technical people available.

Low said that the turning point for the Apollo programme was the 1967 spacecraft fire in which three astronauts perished in a ground test. "In a way, that fire was our own 'Three Mile Island', only the immediate consequence was much worse in that three men died. . . . As a result, however, we had a much better Apollo."

In Search of Planet "X"

Sir, In the February issue of *Spaceflight*, pp. 67–69, A. T. Lawton calls for a search for "missing stars" which might be unrecognized sightings of "planet X". (As an alternative to "Odin", may I suggest "Freya", just to end the near-total male dominance of the planets?).

Lawton concedes that the chances are slim because the planet's maximum brightness is about magnitude 11. However, the August 1979 *Sky & Telescope* contains a possible example on p. 117, in "Astronomical Scrapbook: the Story of the Bond Zones", by Joseph Ashbrook, an account of the Harvard College Observatory's catalogue of equatorial stars. The stars were plotted in overlapping "zones" on successive nights, so that each positional observation could be checked against a previous one. One of the objects was a search for trans-Uranian planets (Neptune had been discovered only six years before the project began).

On 31 March 1859, Sidney Coolidge observed an 11th magnitude object, star 47 in zone 117, with the comment "Has a perceptible disc?" It was not found in zone 118 the following night. Ashbrook gives the 1950 coordinates as 10h 15m 39s, 0° 17'.5. In the same two zones an object 234 was noted as an unidentified asteroid, again of 11th magnitude, "presumably because of the disagreement between the two positions", says Ashbrook.

Presumably the motion of object 234 was direct, and too great for it to be considered a planetary sighting possibility. But "star 47" is much more interesting. If Lawton is correct in supposing that planet X was near Neptune in 1975, then the orbit is retrograde, and inclined to the Ecliptic by at least 10°. The rate of motion is greater than Lawton predicts for "X" if in circular orbit (*Spaceflight*, March 79 pp. 115–123), but a good deal less by my estimate than would have been the case, over the period, if the perihelion distance were as close as Lawton suggests. If therefore it was responsible for the apparent perturbation of Neptune in 1975, "X" must after all be relatively massive. It would be the kind of object postulated by Brady, although the orbital inclination and longitudes of the nodes would be very different.

Lastly, since Coolidge's sighting would be near opposition, the effect of Earth's retrograde motion might have been enough, added to the planet's retrograde motion, to carry it beyond the checking zone, or to change its position in a sufficiently unusual fashion for Coolidge not to recognize it. Thus we need to know the boundaries of the Harvard zones 117 and 118, and – just in case the similar magnitudes confused the issue – the two reported positions of the unidentified asteroid. I have written to Mr. Ashbrook in hopes to find out.

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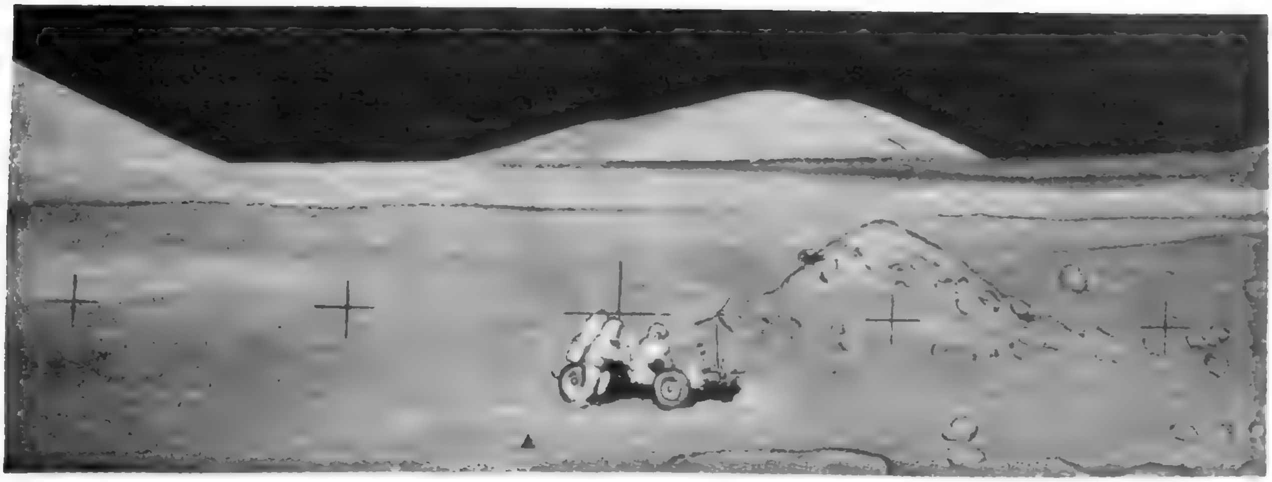
THE MOON TREATY: Its Intentions and Limitations



The U.N. Moon Treaty raises controversial issues because of the restrictions it appears to place on the use of extra-terrestrial resources for commercial purposes. Picture shows Eugene A. Cernan and Dr. Harrison Schmitt, the last of the Apollo astronauts, during their exploration of Taurus-Littrow in December 1972. They obtained 257 lb (116.5 kg) of rock and soil samples. Schmitt was the first qualified geologist to reach the Moon.

NASA

Introduction

Twelve years after the signing of the first United Nations treaty governing activities in outer space, the fifth such treaty on the subject was opened for signature on the 18th December 1979. After some ten years in the making, the Moon Treaty, or more properly, the "Agreement governing the activities of States on the Moon and other celestial bodies" was finally adopted by a Resolution of the United Nations General Assembly.

Although several of the principles of the treaty were already incorporated in the first Outer Space Treaty in 1967, the need for a separate agreement specifically directed at exploration of the Moon had been expressed by several nations, notably the Soviet Union.

The Treaty applies to all bodies in the Solar System and their orbits, as well as the Moon, and restates a number of general principles already established concerning sovereignty and freedom of access, as well as the general prohibition of military activities, and the full text is reproduced below, but it has already given rise to controversy among international lawyers and others in two particular areas.

Firstly, the words "the province of all mankind" when referring to the Moon, which appear in Article IV, have been contrasted with the words "the common heritage of mankind" which appear in Article XI, and questions raised as to whether they bear the same or distinctive meanings. The words "province of all mankind" were used in Article I of the 1967 Space Treaty, while the expression "common heritage" was first used in the seabed analogy at the Law of the Sea Conference, when a moratorium on exploration was later followed by a Resolution of the General Assembly affirming the common heritage principle. The limits of the doctrine have not yet been finally defined in international law, and in this treaty privileges are reserved to States Parties, although "all mankind" are to be the beneficiaries. It would also appear that the concept of the "common heritage of mankind" is limited to the terms of Article XI.1.

Secondly, Article XI, in its paragraph 3, apparently seeks to prohibit any appropriation of resources found on the surface or subsurface of the Moon, and this, in its literal meaning, would seem to preclude any mining or exploitation of valuable minerals which may be found there in the future. However, another view is that this is merely legal language to reaffirm the existing general principle that no legal property in the resources in place can accrue to the exploring state, and certainly the United States delegate to the UN Legal Sub-Committee is confident that no moratorium on exploitation is intended, pending the establishment of an international regime of management as required by Article XI.5. as soon as such exploitation is about to become feasible. It is this requirement which could be said to pre-empt any prior rights which an exploring state might wish to exercise over the extraction of natural resources, and the matter is not entirely free from doubt. While respecting the general principle of non-sovereignty over celestial bodies which is now clearly enshrined in the 1967 Space Treaty, fears have been expressed in some quarters that such a general prohibition will inhibit the Space Powers, particularly the United States, from embarking upon the costly adventure of lunar exploitation while such a restraint exists, or when an international regime of shared resources will result in little or no profit from the venture. This danger is already apparent in the case of deep sea mining, when an international regime is involved.

The taking of samples would seem to involve them becoming the property of the exploring state (Article VI.2.), but mining operations on a regular or systematic basis would bring into force the requirement in Article XI.5. to establish an international regime. It is clearly too early to say how matters will develop, or whether these requirements will be strictly observed, bearing in mind the difficulty of supervision and enforcement. However, opposition to Article XI in the United States has already caused a postponement of the Senate ratification of the Treaty this year.

There are many useful aspects of the Treaty to note, however, when studying the text, notably the affirmation of the demilitarization of the Moon in Article III, which both Space Powers will find valuable from a political and military standpoint. In addition, the environmental aspects of lunar exploration are covered in Article VII, which has provisions akin to those of Article IX of the 1967 Treaty designed to prevent harmful contamination, and all stations and installations on the Moon are to be open to visit by other States Parties to the treaty on the giving of reasonable notice (Article XV), but not apparently, as in the case of Article XII of the 1967 Treaty, on a basis of reciprocity.

As in Article VIII of the earlier treaty, the ownership of all its vehicles and equipment remains with the exploring state, as well as jurisdiction over its personnel. This is in any case a practical reality, and no question of internationalization is thus involved. Article XIV repeats the principle enunciated in Article VII of the 1967 Treaty that states bear international responsibility for national activities on the Moon, and this concept is now reinforced by the 1972 Treaty on Liability so far as damage in space is concerned. There is also a provision in Article XV of this treaty that a State Party which has reason to believe that another State Party is not fulfilling its obligations, or is interfering with that other state's rights, may request consultation, and if such consultation does not lead to a mutually acceptable settlement, the assistance of the Secretary-General of the United Nations may be sought.

Finally, as in the case of the 1967 Treaty, parties may withdraw from this Treaty after one year from its entry into force, and provision is also made for a review of its operation by the United Nations General Assembly after ten years.

The Treaty has controversial aspects which have yet to be fully worked out, but in its favour must be placed the growing desire among nations to bring the Super Powers into a regime with basic ground rules common to all, imperfect though that regime may be, rather than to permit a free-for-all, whether in space or on the seabed or elsewhere in the Earth's environment.

CYRIL E. S. HORSFORD
M.A.(Cantab), FBIS., Barrister,
A Director (1961–1972), International
Institute of Space Law.

Annex

AGREEMENT GOVERNING THE ACTIVITIES OF STATES ON THE MOON AND OTHER CELESTIAL BODIES

The States Parties to this Agreement, *Noting* the achievements of States in the exploration and use of the Moon and other celestial bodies,

Recognizing that the Moon, as a natural satellite of the Earth, has an important role to play in the exploration of outer space,

Determined to promote on the basis of equality the further development of co-operation among States in the exploration and use of the Moon and other celestial bodies,

Desiring to prevent the Moon from becoming an area of international conflict,

Bearing in mind the benefits which may be derived from the exploitation of the natural resources of the Moon and other celestial bodies,

Recalling the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, the Convention on International Liability for Damage Caused by Space Objects, and the Convention on Registration of Objects Launched into Outer Space,

Taking into account the need to define and develop the provisions of these international instruments in relation to the Moon and other celestial bodies, having regard to further progress in the exploration and use of outer space,

Have agreed on the following:

Article I

1. The provisions of this Agreement relating to the Moon shall also apply to other celestial bodies within the Solar System, other than the Earth, except in so far as specific legal norms enter into force with respect to any of these celestial bodies.

2. For the purposes of this Agreement reference to the Moon shall include orbits around or other trajectories to or around it.

3. This Agreement does not apply to extraterrestrial materials which reach the surface of the Earth by natural means.

Article II

All activities on the Moon including its exploration and use, shall be carried out in accordance with international law, in particular, the Charter of the United Nations, and taking into account the Declaration on Principles of International Law concerning Friendly Relations and Co-operation among States in accordance with the Charter of the United Nations, adopted by the General Assembly on 24 October 1970, in the interest of maintaining international peace and security and promoting international co-operation and mutual understanding, and with due regard to the corresponding interests of all other States Parties.

Article III

1. The Moon shall be used by all States Parties exclusively for peaceful purposes.

2. Any threat or use of force or any other hostile act or threat of hostile act on the Moon is prohibited. It is likewise prohibited to use the Moon in order to commit any such act or to engage in any such threat in relation to the Earth, the Moon, spacecraft, the personnel of spacecraft or man-made space objects.

3. States Parties shall not place in orbit around or other trajectory to or around the Moon objects carrying nuclear weapons or any other kinds of weapons of mass destruction or place or use such weapons on or in the Moon.

4. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on the Moon shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration and use of the Moon shall also not be prohibited.

Article IV

1. The exploration and use of the Moon shall be the province of all mankind and shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development. Due regard shall be paid to the interests of present and future generations as well as to the need to promote higher standards of living conditions of economic and social progress and development in accordance with the Charter of the United Nations.

2. States Parties shall be guided by the principle of co-operation and mutual assistance in all their activities concerning the exploration and use of the Moon. International co-operation in pursuance of this Agreement should be as wide as possible and may take place on a multilateral basis, on a bilateral basis, or through international intergovernmental organizations.

Article V

1. States Parties shall inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of their activities concerned with the exploration and use of the Moon. Information on the time, purposes, locations, orbital parameters and duration shall be given in respect of each mission to the Moon as soon as possible after launching, while information on the results of each mission, including scientific results, shall be furnished upon completion of the mission. In case of a mission lasting more than 60 days, information on conduct of the mission including any scientific results shall be given periodically at 30 days' intervals. For missions lasting more than six months, only significant additions to such information need be reported thereafter.

2. If a State Party becomes aware that another State Party plans to operate simultaneously in the same area of or in the same orbit around or trajectory to or around the Moon, it shall promptly inform the other State of the timing of and plans for its own operations.

3. In carrying out activities under this Agreement, States Parties shall promptly inform the Secretary-General, as well as the public and the international scientific community, of any phenomena they discover in outer space, including the Moon, which could endanger human life or health, as well as of any indication of organic life.

Article VI

1. There shall be freedom of scientific investigation on the Moon by all States Parties without discrimination of any kind, on the basis of equality and in accordance with international law.

2. In carrying out scientific investigations and in furtherance of the provisions of this Agreement the States Parties shall have the right to collect on and remove from the Moon samples of its mineral and other substances. Such samples shall remain at the disposal of those States Parties which caused them to be collected and may be used by them for scientific purposes. States Parties shall have regard to the desirability of making a portion of such samples available to other interested States Parties and the international scientific community for scientific investigation. States Parties may in the course of scientific investigations also use mineral and other substances of the Moon in quantities appropriate for the support of their missions.

3. States Parties agree on the desirability of exchanging scientific and other personnel on expeditions to or installations on the Moon to the greatest extent feasible and practicable.

Article VII

1. In exploring and using the Moon, States Parties shall take measures to prevent the disruption of the existing balance of its environment whether by introducing adverse changes in such environment, its harmful contamination through the introduction of extra-environmental matter or otherwise. States Parties shall also take measures to prevent harmfully affecting the environment of the earth through the introduction of extraterrestrial matter or otherwise.

2. States Parties shall inform the Secretary-General of the United Nations of the measures being adopted by them in accordance with paragraph 1 of this article and shall also to the maximum extent feasible notify him in advance of all placements by them of radioactive materials on the Moon and of the purposes of such placements.

3. States Parties shall report to other States Parties and to the Secretary-General concerning areas of the Moon having special scientific interest in order that, without prejudice to the rights of other States Parties, consideration may be given to the designation of such areas as international scientific preserves for which special protective arrangements are to be agreed in consultation with the competent organs of the United Nations.

Article VIII

1. States Parties may pursue their activities in the exploration and use of the Moon anywhere on or below its surface, subject to the provisions of this Agreement.

2. For these purposes States Parties may, in particular:
(a) Land their space objects on the Moon and launch them from the Moon;
(b) Place their personnel, space vehicles, equipment, facilities, stations and installations anywhere on or below the surface of the Moon.

Personnel, space vehicles, equipment, facilities, stations and installations may move or be moved freely over or below the surface of the Moon.

3. Activities of States Parties in accordance with paragraphs 1 and 2 of this article shall not interfere with the activities of other States Parties on the Moon. Where such interference may occur, the States Parties concerned shall undertake consultations in accordance with article XV, paragraphs 2 and 3.

Article IX

1. States Parties may establish manned and unmanned stations on the Moon. A State Party establishing a station shall use only that area which is required for the needs of the station and shall immediately inform the Secretary-General of the United Nations of the location and purposes of that station. Subsequently, at annual intervals that State shall likewise inform the Secretary-General whether the station continues in use and whether its purposes have changed.

2. Stations shall be installed in such a manner that they do not impede the free access to all areas of the Moon of personnel, vehicles and equipment of other States Parties conducting activities on the Moon in accordance with the provisions of this Agreement or of article I of the Treaty on Principles Covering the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies.

Article X

1. States Parties shall adopt all practicable measures to safeguard the life and health of persons on the Moon. For this purpose they shall regard any person on the Moon as an astronaut within the meaning of article V of the Treaty on Principles Governing the Activities of States on the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies and as part of the personnel of a spacecraft within the meaning of the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space.

2. States Parties shall offer shelter in their stations, installations, vehicles and other facilities to persons in distress on the Moon.

Article XI

1. The Moon and its natural resources are the common heritage of mankind which finds its expression in the provisions of this agreement and in particular in paragraph 5 of this article.

2. The Moon is not subject to national appropriation by any claim of sovereignty, by means of use or occupation, or by any other means.

3. Neither the surface nor the subsurface of the Moon, nor any part thereof or natural resources in place, shall become property of any State, international intergovernmental or non-governmental organization, national organization or non-governmental entity or of any natural person. The placement of personnel, space vehicles, equipment facilities, stations and installations on or below the surface of the Moon, including structures connected with their surface or subsurface, shall not create a right of ownership over the surface or the subsurface of the Moon or any areas thereof. The foregoing provisions are without prejudice to the international regime referred to in paragraph 5 of this article.

4. States Parties have the right to exploration and use of the Moon without discrimination of any kind on a basis of equality, and in accordance with international law and the terms of this Agreement.

5. States Parties to this Agreement hereby undertake to establish an international régime, including appropriate procedures, to govern the exploitation of the natural resources of the Moon as such exploitation is about to become feasible. This provision shall be implemented in accordance with article XVIII of this Agreement.

6. In order to facilitate the establishment of the international régime referred to in paragraph 5 of this article, States Parties shall inform the Secretary-General of the United Nations as well as the public and the international scientific community to the greatest extent feasible and practicable of any natural resources they may discover on the Moon.

7. The main purposes of the international régime to be established shall include:
(a) The orderly and safe development of the natural resources of the Moon;
(b) The rational management of those resources;
(c) The expansion of opportunities in the use of those resources; and
(d) An equitable sharing by all States Parties in the benefits derived from those resources,

whereby the interests and needs of the developing countries as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the Moon shall be given special consideration.

8. All the activities with respect to the natural resources of the Moon shall be carried out in a manner compatible with the purposes specified in paragraph 7 of this article and the provisions of article VI, paragraph 2, of this Agreement.

Article XII

1. States Parties shall retain jurisdiction and control over their personnel, vehicles, equipment, facilities, stations and installations on the Moon. The ownership of space vehicles, equipment, facilities, stations and installations shall not be affected by their presence on the Moon.

2. Vehicles, installations and equipment or their component parts found in places other than their intended location shall be dealt with in accordance with article V of the Agreement on Assistance to Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space.

3. In the event of an emergency involving a threat to human life, States Parties may use the equipment, vehicles, installations, facilities or supplies of other States Parties on the Moon. Prompt notification of such use shall be made to the Secretary-General of the United Nations or State Party concerned.

Article XIII

A State Party which learns of the crash landing, forced landing or other unintended landing on the Moon of a space object, or its component parts, that were not launched by it, shall promptly inform the launching State Party and the Secretary-General of the United Nations.

Article XIV

1. States Parties to this Agreement shall bear international responsibility for national activities on the Moon whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Agreement. States Parties shall ensure that non-governmental entities under their jurisdiction shall engage in activities on the Moon only under the authority and continuing supervision of the appropriate State Party.

2. States Parties recognize that detailed arrangements concerning liability for damage sustained on the Moon, in addition to the provisions of the Treaty on Principles Covering the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies and the Convention on International Liability for Damage Caused by Space Objects, may become necessary as a result of more extensive activities on the Moon. Any such arrangements shall be elaborated in accordance with the procedure provided for in article XVIII of this Agreement.

Article XV

1. Each State Party may assure itself that the activities of other States Parties in the exploration and use of the Moon are compatible with the provisions of this Agreement. To this end, all space vehicles, equipment, facilities, stations and installations on the Moon shall be open to other States Parties. Such States Parties shall give reasonable advance notice of a projected visit, in order that appropriate consultations may be held and that maximum precautions may be taken to assure safety and to avoid interference with normal operations in the facility to be visited. In pursuance of this article, any State Party may act on its own behalf or with the full or partial assistance of any other State Party or through appropriate international procedures within

the framework of the United Nations and in accordance with the Charter.

2. A State Party which has reason to believe that another State Party is not fulfilling the obligations incumbent upon it pursuant to this Agreement or that another State Party is interfering with the rights which the former State has under this Agreement may request consultations with that Party. A State Party receiving such a request shall enter into such consultations without delay. Any other State Party which requests to do so shall be entitled to take part in the consultations. Each State Party participating in such consultations shall seek a mutually acceptable resolution of any controversy and shall bear in mind the rights and interests of all States Parties. The Secretary-General of the United Nations shall be informed of the results of the consultations and transmit the information received to all States Parties concerned.

3. If the consultations do not lead to a mutually acceptable settlement which has due regard for the rights and interests of all the States Parties, the parties concerned shall take all measures to settle the dispute by other peaceful means of their choice and appropriate to the circumstances and the nature of the dispute. If difficulties arise in connexion with the opening of consultations or if consultations do not lead to a mutually acceptable settlement, any State Party may seek the assistance of the Secretary-General without seeking the consent of any other State Party concerned, in order to resolve the controversy. A State Party which does not maintain diplomatic relations with another State Party concerned shall participate in such consultations, at its choice, either itself or through another State Party or the Secretary-General, as intermediary.

Article XVI

With the exception of articles XVII to XXI, references in this Agreement to States shall be deemed to apply to any international intergovernmental organization which conducts space activities if the organization declares its acceptance of the rights and obligations provided for in this Agreement and if a majority of the States members of the organization are States Parties to this Agreement and to the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies. States members of any such organization which are States Parties to this Agreement shall take all appropriate steps to ensure that the organization makes a declaration in accordance with the foregoing.

Article XVII

Any State Party to this Agreement may propose amendments to the Agreement. Amendments shall enter into force for each State Party to the Agreement accepting the amendments upon their acceptance by a majority of the States Parties to the Agreement and thereafter for each remaining State Party to the Agreement on the date of acceptance by it.

Article XVIII

Ten years after the entry into force of this Agreement, the question of the review of the Agreement shall be included in the provisional agenda of the United Nations General Assembly in order to consider, in the light of past application of the Agreement, whether it requires revision. However, at any time after the Agreement has been in force for five years, the Secretary-General of the United Nations, as depository, shall, at the request of one third of the States Parties to the Agreement and with the concurrence of the majority of the States Parties, convene a conference of the States Parties to review this Agreement. A review conference shall also consider the question of the implementation of the provisions of article XI, paragraph 5, on the basis of the principle referred to in paragraph 1 of that article and taking into account in particular any relevant technological developments.

Article XIX

1. This Agreement shall be open for signature by all States at United Nations Headquarters in New York.

2. This Agreement shall be subject to ratification by signatory States. Any State which does not sign this Agreement before its entry into force in accordance with paragraph 3 of this article may accede to it at any time. Instruments of ratification or accession shall be deposited with the Secretary-General of the United Nations.

3. This Agreement shall enter into force on the thirtieth day following the date of deposit of the fifth instrument of ratification.

4. For each State depositing its instrument of ratification or accession after the entry into force of this Agreement, it shall enter into force on the thirtieth day following the date of deposit of such instrument.

5. The Secretary-General shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification or accession to this Agreement, the date of its entry into force and other notices.

Article XX

Any State Party to this Agreement may give notice of its withdrawal from the Agreement one year after its entry into force by written notification to the Secretary-General of the United Nations. Such withdrawal shall take effect one year from the date of receipt of this notification.

Article XXI

The original of this Agreement, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations, who shall send certified copies thereof to all signatory and acceding States.

IN WITNESS WHEREOF the undersigned, being duly authorized thereto by their respective Governments, have signed this Agreement, opened for signature at New York on 18 December 1979.

MILESTONES/*Continued from p. 269]*

concerning the high pressure turbopumps, valves and nozzles. Each engine will be operated on the test stands of the National Space Technology Laboratories, Bay St. Louis, Mississippi. Afterwards, the engines will be returned to KSC for re-installation in "Columbia". About six weeks before the first flight, the engines will be fired once again, for 20 seconds, on the launch pad. The testing (says NASA) "is expected to have no effect on the timing of the Shuttle's first flight, now anticipated between November 1980 and March 1981."

6 NASA announces the discovery of a new moon of Jupiter – its 15th – during a search of photographs obtained by Voyager 1 when it passed the giant planet on 5 March 1979. The moon, only 70 to 80 km across and provisionally called 1979 J2, is the second to have been found from Voyager photographs. It orbits Jupiter every 16 hr 16 min at a distance of 151,100 km above the cloud tops. Discovery was made by JPL scientist Dr. Stephen P. Synnott of the Voyager Optical Navigation team.

8 NASA and the European Space Agency select 37 experiments to be conducted on the first flight of Spacelab, scheduled for launch aboard the Space Shuttle in late 1982. The experiments fall into broad categories: atmospheric physics and Earth observations; space plasma physics; material sciences and technology; astronomy and solar physics, and the life sciences. Thirteen are sponsored by NASA; the remainder by ESA. The Spacelab 1 mission is to be conducted jointly by the two agencies. Five Payload Specialists, two Americans and three Europeans, are now training for the first mission. Two of this group, an American and a European, will fly aboard Spacelab 1. The other three will operate ground-based experiment equipment and assist the pair in orbit.

9 New China News Agency announces that "carrier rockets" will be launched from the Chinese mainland to a target area in the South Pacific between 10 May and 12 June. Ships and aircraft are requested not to enter an area 70 miles (112 km) in radius centred at 7 deg S, latitude, 171 deg 33 min E longitude, in the region of the Solomon Islands northwest of Fiji.

9 Rockwell International Space Systems Group gives the following account of work remaining to be done on the Thermal Protection System of Space Shuttle "Columbia" at KSC. "We're in the final stages of deciding which 'tiles' do not have to be tested or removed, if any are in that category. At worst, we could have to install – or re-install – a total of about 10,000 to 11,000 encompassing an additional three or three and one-half months". [*As previously explained*], "the 'tiles' go through a densification process which increases the strength of the bonded surface by a factor of two-to-four. The densified 'tiles', when bonded with Room Temperature Vulcanizer (RTV) to the Strain Isolator Pad, literally can't be pulled off. The densification process, which was a development by several NASA Johnson Space Center people and several Rockwell materials and development units and labs, was, or is, a real winner. Installation of the 'tiles' has been averaging about 700 800 per week, and it is anticipated that rate will increase to the 800-plus category later this month or early next." (*See also pages 290-291*).

NASA 1981: THE BUDGET AND THE PROSPECT

By David Baker

Introduction

There is no better way to measure the shape of a future aerospace programme than to examine the funding profile of its research and development plan. In a labour-intensive agency where more than 8½ dollars out of every 10 support manpower needs it is as much a reflection of personnel requirements as it is of the technology base. So, when NASA was allowed to request a significant increase in its proposed fiscal year 1981 budget, hopes were high that confidence in space operations had been regained. Not since Lyndon Johnson has a U.S. President backed verbal rhetoric with cash on the table but President Carter seems to have a reason now for giving NASA the money it needs to move ahead. The nature of that reason, however, is one not likely to give NASA much cause for rejoicing.

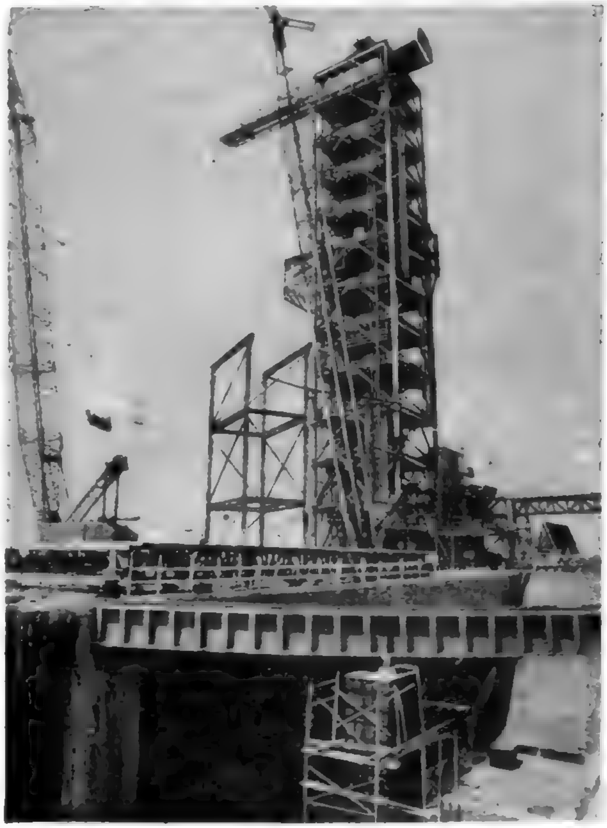
In the wake of a worsening political balance between the United States and less friendly powers, Carter has revitalized a segment of space spending devoted to military programmes aimed at bolstering confidence in the armed forces. But more than that, for even before Soviet infantry divisions rolled south across the Afghanistan border, limitations contained in the SALT-II agreement called for a better surveillance of Russian hardware. And that, in turn, called for more money to develop and launch a new generation of reconnaissance, ferret, and observation satellites.

Last year, long before Carter's foreign policy advisers warned of an imminent Soviet initiative, the need to convince Congressional anti-SALT forces that America would very soon have the tools to monitor and verify terms and conditions of the agreement led to massive increases in defence money allocated to space. It was vital to speed work based on plans and proposals mooted during the Ford administration's tenure, but for which there was now a tangible cause; without such means of verification many votes would be lost in the bid to ratify SALT-II.

As events turned out, those boosts were needed to show increasing concern for America's defences in the wake of Soviet action. Between 1978 and 1980 the amount of money allocated to space by civilian and military authorities increased by 33% but NASA got an increase of only 15% while the Defence Department's space money went up by 58%. Set against the dollar, that 15% hardly kept pace with inflation while the Defence Department segment gained on the cost index by a significant margin. The reasons are of course easy to define and reflect an increasing concern for the military role of manned and unmanned space systems. Accordingly, within the climate of increasing financial resources for space, the civilian NASA hardly keep up with rising costs. And that is a disastrous situation when the agency is on the verge of introducing a completely new concept in space transportation and should be thinking of ways to maximize the investment.

It is the Shuttle that seemingly keeps NASA against the wall because massive increases in development money starve other programmes, and it is the reusable launcher that bolsters defence projects claiming major increases in that sector. The net result is that within an ostensible healthy space industry, civilian projects get beaten to the post at every turn while investment for active military systems goes up.

It is important that everyone associated with the business of designing, building, launching and operating satellites for exploration or Earth applications understand the consequences of a shift from scientific to military activity. For while NASA continues to operate, laudibly, in the spotlight of public attention, several military developments are veiled under broad categories not directly associated with space activity. So it is with pressures for more Shuttle money undeniably linked to a need to get it flying for military payload schedules that the agency is starved for funds for projects necessary to sustain momentum in the civilian sector.



SECOND SHUTTLE PAD. Construction work underway at Launch Complex 39B at the Kennedy Space Center to prepare for Shuttle launches in the 1980's. The Pad was last used for the last Saturn launch, Apollo-Soyuz, in 1975.

Stephen Smyth

It must be clearly understood that the author is not calling for a halt to the military exploitation of space; several essential initiatives have been left too long in the "pending" tray. But the value of having separate functional structures to administer civilian and military programmes is in danger of eroding to a Soviet style *pot-pourri* of jumbled and clandestine activities where the barriers are deliberately laid low "in the national interest." The great strength of American and European space activity lies in the free and uninhibited way scientists and users can take part in clearly civilian projects.

The story of Shuttle funding over the last three years mirrors concern expressed in NASA much earlier in the last decade. Nearly ten years ago high management personnel warned Administrator Jim Fletcher of the danger in "bone-cutting" the Shuttle estimates. Readers will recall that at the end of the 1960's commissioned studies of Shuttle type spacecraft showed a probable development cost of around 7–8 thousand million dollars for the current, partially expendable, system, not the fully reusable system the agency wanted from the outset. Instead, Office of Management & Budget restrained the agency from an all-out start until it came up with an estimate no greater than 5,150 million dollars in 1972 money.

Now, the gap between the figure NASA origally stated and that it internally feared would be the real cost has emerged in a flurry of requests for supplemental funds hitting the 1979 and 1980 budgets, inflating the 1981 request beyond all expectations, and severely limiting the possibilities for projects in the next few years. Earlier reports published by this author show dramatic increases between the sum NASA thought it

would need for Shuttle development and the money it finally spent, borrowing from other categories until, in 1979, that too ran dry.

In FY1976 the agency spent 0.08% more on Shuttle R&D than it said it would at the beginning of that year; in 1977 expenditure was up 7%; in 1978, 11.5%; and in 1979, 30.7%. The last report ("Programming the Shuttle to Future Needs," *Spaceflight*, Vol. 22, No. 3, March 1980) examined the FY1980 request which by the middle of the last year had already grown by an estimated 34.4% A brief review of those profiles may help here.

For FY1979 NASA requested $857.2 million to spend on Orbiter, main engine, solid booster and external tank development, actually spending $1,120.7 million by way of supplementals and borrowing from the production fund, a separate part of the Shuttle budget. (It is interesting to note that this figure is up yet again on the estimate given in the former report but is now considered final because the fiscal year ended November 1 last, which accounts for the slight inaccuracy earlier since that report was written before the end of the financial period). For fiscal year 1980, the period ending November 1 this year, NASA has inflated its original development request for $511.3 million first to $687.3 million and then again to $942.1 million. This represents a FY1980 expenditure of 83.2% above the figure estimated one year ago.

It should be noted that the quoted figures relate only to development and that other increases have also been requested for production, etc., as reflected in the accompanying table.

The frequency with which the supplementals have been requested has caused alarm in some Congressional circles about the stability of NASA funding estimates. For an agency with such a tidy financial record, they say, it is surprising to see such a tirade of new requests. The history does indeed create interesting reading.

After submitting the formal FY1980 request in January last year, including a sum of $185 million for FY1979, the agency came back through President Carter on May 14 with a further request for an extra $220 million, adding an additional $300 million when the FY1981 budget was presented January last. Not surprizingly, Administrator Frosch does not "expect the 1980 budget year to go down in history as my favourite."

But the real reasons for this inflation between estimates and dollar expenditure stems from fixed funding levels early in the 1970's when the then Administrator and his President played caretaker roles unwillingly tied to a flagging national economy. As it is, there have been some apalling increases in raw materials and services for which the agency is particularly sensitive, inflationary factors impossible to foresee a decade ago when Rockwell got the Orbiter and Shuttle integration contract.

From an estimated annual wage increase of 4.5%, the Space Systems Group has experienced annual personnel increases of an average 10%. In a contract where 80% of the cost-before-fee price goes on salaries and wages, that is potentially dangerous. In 1972 when Rockwell started formal work on the definitive Shuttle, the Consumer Price Index quoted by the Government anticipated an average increase of 3% (hence the 4.5% Rockwell prediction for wage rises). But in fact, the 1970's averaged price increases of more than 8% each year, confounding the original Shuttle development tag.

Moreover, the Government told Rockwell that added security taxes would rise by an expected 10% per annum whereas in reality that figure has been doubled to pay for increasingly accommodating welfare commitments. In Florida, a decision by the Government to use Kennedy Space Centre for a wage determination process has forced NASA to pay wages 54% higher than elsewhere in Brevard County, again forcing massive inflation.

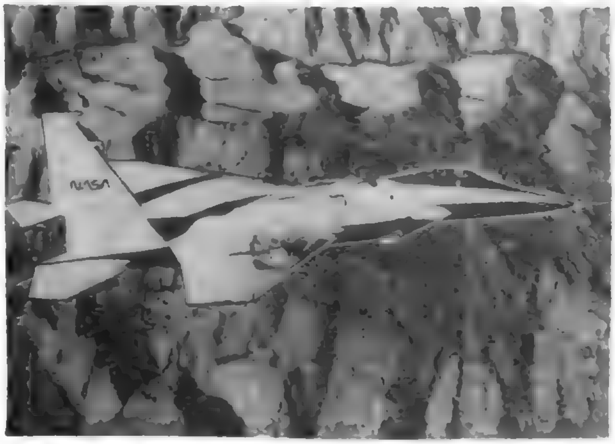
But the real reason for cost increases in the Shuttle fund is basically due to four primary causes: a serious weight increase in Orbiters; trouble with tile fabrication and emplacement; serious main engine problems which still threaten flight dates; and unparalleled commodity cost increases. Last year was the worst the agency expects to weather on Shuttle budget tussles, as reflected by the three supplementals in the twelve months ending January, 1980. Examples show the severity of cost increases.

In the year ending April, 1979, aluminium sheet, bar and plate costs rose 35–46%; Martin Marietta reports 2219 aluminium sheet plate and forgings has gone up by 74.2% in the four years ending April 1979; in the same period, Rockwell found fittings, fasteners, bolts, electrical connectors, and seals had risen by up to 63%; solid rocket booster component costs have increased by 38–70% in three years; equipment for the Shuttle launch pad at KSC has risen by 202–875%; and shipment costs of major elements like the booster segments has risen by 34–72%.

Main engine troubles have been well documented already in several items carried by *Spaceflight* but suffice it to say that the failure on February 1 to get the full duration firing of a three-engine cluster will probably add further delay to an already extended schedule. Tile fabrication continues to be the major pacing item for first flight. But here too unexpected trouble with the type of work each contractor was expected to accomplish has led to the worse kind of domino effect.

To begin with, Lockheed set out in 1973 its funding and delivery schedules for Rockwell to receive batches of 250–500 tiles in kits from which they could sand and shape the individual bricks. Under a $20.6 million effort, Lockheed was only to be required to supply rough-fit tiles. But the original plan to use flat, square-shaped, tiles was replaced first by a need for better shaping and then for each tile to be unique to its assigned location on the Orbiter. These changes pushed Lockheed's contract up to $122.7 million.

Each tile now had to be contoured and machined on numerically-controlled equipment at Lockheed. A major problem was presented by the work process; a challenge to management and personnel profiles. Lockheed was to separate data from Rockwell on each specific tile into special routines, converting the master dimension data into extremely accurate numerically controlled cut package tapes for the NC mills required to shape each tile differently. Rockwell delivers data to Lockheed



SPACE SHUTTLE thermal protection tiles being flight tested on an F-15 research aircraft from the Dryden Flight Research Center. The tiles will eventually be submitted to almost one and one-half the dynamic pressure that the Shuttle will attain during launch. The tiles on the F-15's starboard wing are simulating the leading edge of the Orbiter's wing while the tiles on the port wing represent the tiles on the junction of the Orbiter's wing and fuselage. The tests are part of the overall verification tests of the various Shuttle systems (see also pages 290–291).

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in two forms: layout diagrams for the complete array of tiles and drawings of each individual tile. The details of each tile, however, are set up on magnetic tapes and in master dimension drawing books so the fabrication of tiles must necessarily proceed on figures provided by the customer. Errors unavoidably creep in and subtle changes in the geometry of specific tiles inevitably brings a high rejection rate.

Each of the approximately 34,500 separate tiles has its own IBM computer card and the dimensions are further complicated by a need to compensate for shrinkage during glazing, which is always an approximation. Each tile has a size tolerance requiring it to be within 0.4-mm of the specified dimension. There is increasing interest within NASA on the new materials proposed by Lockheed. Fibre Reinforced Composite Insulation (FRCI) is currently seen as providing longer life for tiles exposed to hot areas on the Orbiter. By replacing boron oxide contained in the tile chemistry with a germanium oxide, temperatures increase from a design limit of 1,260°C to almost 1,600°C.

In adopting materials capable of withstanding higher temperatures the unit life of each tile should increase appreciably. Also, development of a new low-temperature glazing process should produce much less distortion in the finished product, retaining the same survival bands but improving the quality. Called RCC Class 2 (Reaction-Cured Glass), the curing temperature could be reduced from 1,204°C to 1,010°C. Moreover, a new boron-rich refractory fibre composite material developed with strong support from the NASA Ames Research Centre promises to provide a three-fold increase in strength, an increase of 55°C in survival temperature, no crack propagation and direct bonding without the need for an isolator pad.

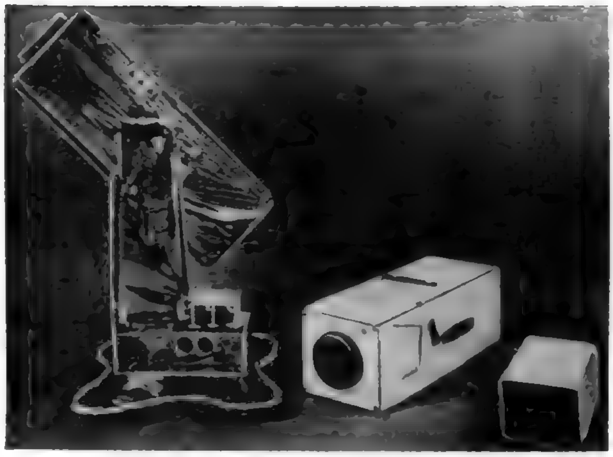
Compared with the conventional basic material (LI-900), the new boron fibre FRCI has a tensile strength better by a factor of three, with a higher coefficient of expansion, thereby putting the coating into compression and reducing the probability of cracks. It is the brittle nature of the basic material that has brought so many problems to tile fabrication and emplacement, threatening to collapse under the more extreme dynamics of a fully stressed Shuttle flight.

Serious overweight problems with the first two operational Orbiters has been discussed by this author in an earlier report and suffice it to say now that NASA has decided to develop a supplementary propulsion unit based on the Titan liquid-propellant system fixed beneath the External Tank. With this in place, defence milestones will be met in flights from Vandenberg Air Force Base beginning 1985.

If plans now laid by the space agency reach fruition, Columbia will move to the Vehicle Assembly Building in August followed by roll-out to the launch pad a month later. The first flight is now expected during the first quarter of 1981 and would be followed by four or five development missions to explore every fold of the Shuttle's performance envelope. Manned Spacelab flights should be under way by mid-1982. Delivery of the second, third and fourth Orbiters is presently scheduled for March, 1982, summer 1983, and fall 1984, respectively.

No decision has yet been made concerning a fifth Orbiter and a necessity to have that vehicle funded by FY1981 or suffer severe lay-offs at Rockwell has receded along with the postponed launch date for Columbia. However, long-lead items must be procured ready for full production authority by FY1982, at which time plans would emerge for a roll-out in the first quater of 1986, the earliest date now envisaged for the fifth vehicle. Opinion on the need for a fifth Orbiter is mixed. NASA is certain that if a decision is not made by FY1983 the completion of large structural subcontract work on Orbiter 104 would render the possibility of a fifth vehicle untenable.

The space agency recognises only too well that Congressional patience is strictly limited and that consistent submittals for more money are causing hitherto ardent supporters to question the viability of NASA's costing machine. When asked



SHUTTLE CAMERA. Enclosed in an insulating layer of gold foil is one of the 16 lb (7.2 kg) closed circuit television cameras being built for the Space Shuttle. The RCA cameras will be used to guide the astronauts in handling payloads and in deploying and retrieving satellites. They also will transmit signals back to Earth so that TV audiences will be able to watch colour coverage of various space activities.

NASA

for support in passing the bill for a supplemental last year, Senator Stevenson (Illinois) said:

"With the country in its present mood, I am not sure that is very realistic unless, of course, we demonstrate that this programme is going to be better managed than it has been in recent years. Am I wrong? Have we been, year after year after year, misled – the costs underestimated year after year? If not, then it seems rather clear to me that there has been some serious negligence in these programmes ... Our Committee and the Appropriations Committee received these estimates about a month before you came in with the overruns. Something didn't happen in just 30 days."

Dr Jerry Grey from the American Institute for Aeronautics and Astronautics expressed the viewpoint succinctly when asked if NASA really needed a fifth Orbiter:

"We feel the chance of some idiot driving a tank truck into one while it's on the ground ... is too high not to have the option of ... providing a backup capability."

But failures on the ground are not the only threat to full Shuttle operations. If one Orbiter were to be lost in space, or during descent, there would be no margin left and a resulting need to buy back the expendables Shuttle was built to replace would all but destroy the economics of reusability. In a frank appraisal of the technical risks involved with the Shuttle, several respected authorities recently submitted reports to NASA Administrator Robert Frosch after being asked to review the programme for headquarters and management personnel.

Ex-Apollo 8 astronaut William A. Anders told Frosch that "Though the safety margins may be adquate under an aircraft testing philosophy (tuning the Shuttle to airline-like operation has been a key programme guide star), the Shuttle is still the preeminent US spacecraft ... Though I would test fly the Shuttle (if problems are addressed as expected), I would worry more about it than I did for Apollo 8 due to narrower safety margins (e.g. fallout from reduced hardware qualifications and unmanned flight testing). I believe that this narrower-than-Apollo-margins situation should be brought to the attention of the President ..."

Vice-Admiral Levering Smith was concerned "It seems quite likely to me that, at this relatively late date, this schedule, even when adequately funded, could significantly improve the "narrow-than-Apollo-margins" now planned. To reduce the

resultant risk of a major flight failure, I recommend the preparation and adoption of a quite detailed set of criteria to be satisfied as a pre-condition to authorizing first flight."

And Robert Charpie too, felt that "it is prudent for NASA to give the President the timely opportunity to understand the implications of a 'ready-to-fly' decision by the Agency."

The idea that NASA's Shuttle is operationally less safe than Apollo seems a new concept to the political administration but in a climate of examination and analysis it is important that such matters should be emphasized. All too frequently, vehicles designed and developed for routine operations are instinctively considered safer or functionally less critical than custom-built hardware; such opinions are usually relegated to a lay analysis of the type used by political leaders.

NASA's 1981 budget provides fewer starts than had been hoped because the agency has increased by almost $1,000 million the amount it has requested for the Shuttle compared with sums it estimated a year ago. Excluding aeronautics, NASA has been allowed to request $5,446 million, up 9.8 per cent on the 1980 total which has been inflated by the new supplemental. Of this, $4,278 million is for research and development, of which nearly 44 per cent is to be spent on Shuttle development and production. Yet for all the pessimism encouraged by escalating programme costs and massive supplementals there is perhaps after all signs of a gradual up-turn in prospects for new starts from 1982.

For the first time in 15 years the employment situation reverses the continual fall in permanent positions. In 1966 NASA had about 34,000 people; in 1981 positions will rise by 100 to a total 22,713. But major increases in the 1981 Shuttle budget have reduced new-start money this year from an expected $129 million to a mere $24.9 million, sufficient for a start on the Gamma Ray Observatory and on the National Oceanic Satellite System, or NOSS. This latter project is again one suited in concept to defence needs, the Defence Department paying 50 per cent and NASA splitting the balance with the National Oceanic and Atmospheric Administration.

Based on predictions from the Office of Management & Budget that NASA will be allowed to use only one-half the funding wedge vacated by reduced Shuttle development money, next year's budget is expected to yield $170 million for new starts with a further $200 million in 1983. Despite vehement opposition to OMB cuts in the proposed Halley comet rendezvous mission, NASA was unable to retain this programme as a new start for FY1981 and has yet to decide on a less scientifically desirable option to fund a quick ballistic fly-by which planetologists and physicists say is meaningless.

Planetary research now accounts for only 3 per cent of NASA's annual budget and is in serious danger of eroding still further the already depleted prospects for another "decade of the planets" like that just ended. When asked by President Carter to recommend either the Gamma Ray Observatory or the comet mission, Administrator Frosch preferred to choose the former because "The GRO was then and still is in a much better state of detailed definition as a spacecraft and as a programme than the comet mission was," and that "GRO is a more fundamental mission in the sense that large-scale cosmic physics is more fundamental than solar system understanding."

The comet mission relied totally on development of the solar electric propulsion system (SEPS) to boost it from Earth orbit to a rendezvous trajectory with Halley in 1985 and then Tempel II three years later. Because the alignment of the major planets in the Solar System is moving further from the quick-trip options used by Voyager 1 and 2, development of such a useful method of propulsion would have found application in almost all outer-planet missions from now on. Indeed, it would have made possible missions which will probably not now take place.

Once every 179 years or thereabouts the outer planets position themselves for rapid "slingshot" trajectories using the gravity of one to accelerate to another. SEPS would have retained that quick-trip capability making flights to Saturn, Uranus and Neptune meaningful scientific objectives for the 1990's. Over four years, SEPS would have cost NASA a total $200 million to develop for operational use (many years of research and development are already over), about as much as the money allocated to the Galileo project in 1980 and 1981.

As it is, the Gamma Ray Observatory project has been bouncing around the budget corridors for more than two years until finally called up for approval in the FY1981 submission. It is a fallout from the highly successful HEAO programme, three satellites from which have provided significant information about high-energy radiation sources in the Universe. HEAO would at one time have emerged as a much more ambitious endeavour than the finally approved project. It is not a good thing to play catch-up over successive years and

NASA FY1981 BUDGET

	FY1980	*FY1981*
RESEARCH AND DEVELOPMENT	*4,107.500*	4,569.500
Space Transportation Systems	*2,403.300*	*2,738.200*
Space Shuttle	*1,886.00*	*1,873.000*
DDT&E	(1,030.500)	(683.000)
Orbiter	560.900	320.900
Main Engine	140.600	145.700
External Tanks	79.400	48.000
Solid Rocket Boosters	61.200	14.000
Launch & Landing	188.400	154.400
Changes/systems upgrading	(100.000)	(150.000)
Production	(755.500)	(1,040.000)
Orbiter	572.600	768.200
Main Engine	123.600	121.500
Launch & Landing	16.400	440.400
Spares & Equipment	42.900	109.900
Space Flight Operations	*446.600*	*809.500*
Space Transportation System	54.100	89.000
Spacelab	58.800	151.700
STS operations	148.100	374.500
Development, test & mission support	172.600	183.500
Advanced programmes	13.000	10.800
Expendable Launch Vehicles	*70.700*	*55.700*
Space Science	*600.800*	*668.000*
Physics & Astronomy	337.100	438.700
Planetary Exploration	219.900	179.600
Life Sciences	43.800	49.700
Space & Terrestrial Applications	*343.900*	*394.800*
Space Applications	331.800	381.700
Technology Utilization	12.100	13.100
Aeronautics & Space Technology	*327.100*	*409.500*
Aeronautical Research & Technology	308.300	290.300
Space Research & Technology	115.800	115.200
Energy Technology	3.000	4.000
Space Tracking & Data Systems	*332.400*	*359.000*
CONSTRUCTION OF FACILITIES	*156.100*	*120.000*
Shuttle	*32.000*	*11.717*
Non-Shuttle	*125.600*	*108.283*
RESEARCH AND PROGRAMME MANAGEMENT	*1,006.186*	*1,047.154*
TOTAL BUDGET PLAN	5,269.786	5,736.654
OUTLAYS	5,012.600	5,439.700

Note: FY1980 includes proposed supplemental of $300 million for the Shuttle and $46.286 million to cover revised salaries effective October, 1979. All amounts in millions of dollars.

starve funds for major technology developments likely to improve a complete range of mission options.

But for all that, GRO is a visible sign of NASA's increasing concern with the astronomy side of its research; denied many interesting programmes in the 1970's, the astronomical fraternity is finally getting more attention. Following hard on the heels of high-energy observatories, GRO will be launched in 1985, two years after the Space Telescope. Nevertheless, planetary exploration during the 1980's will be a poor shadow of the previous decade, with only a single Jupiter orbiter-probe mission scheduled after a dual fly-by of Saturn and possible fly-by of Uranus.

The Galileo Jupiter mission has been put back two years from the originally planned launch date in 1982 by a projected deficiency between the weight of the spacecraft and the Shuttle's calculated payload capacity. Two separate launches will now be needed to send probe and orbiter vehicles on the Galileo mission which, with development and launch costs included, will force the programme up from an estimated $500 million to about $700 million.

Because of the massive increase in projected Shuttle needs, programmes submitted by NASA and cancelled by the OMB prior to formal presentation of the FY1981 budget include the Venus Orbiter Imaging Radar (VOIR) mission to Venus, a power-extension package to provide the Shuttle with additional electrical energy, a multispectral scanner for Earth resource vehicles, an upper atmosphere Explorer type spacecraft, the comet rendezvous mission, and long-lead procurement money for a fifth Shuttle Orbiter.

Although not the concern of this report, funds were similarly slashed for aeronautical technology research including development of alternative fuels.

Because many payload planners have deferred flights on expendable rockets for a place aboard the Shuttle, NASA will launch in 1980 fewer satellites than in any single year since its formation in October, 1958. Moreover, only one launch is generated by NASA, the remainder being reimbursable flights for paying customers. Reimbursable work brought $269.4 million in 1978, an estimated $332.7 million for 1979 and approximately $356.4 million for 1980.

Following the successful launch on 17 January of the Defence Department's FLTSATCOM-C, and the NASA Solar Maximum Mission in February, the agency plans to send NOAA-B, a weather satellite, up in July from Vandenberg, followed by GOES-D in August from KSC and the first of the Intelsat V communication satellites in September. A Satellite Business Systems communication satellite is scheduled to fly in October followed by the fourth FLTSATCOM and the second Intelsat V a month later. In all, eight scheduled missions plus two call-ups involving Transit navigation satellites for the Navy should existing satellites fail.

NASA asked for $6,040 million in FY1981 and received cuts totalling more than $300 million. It remains to be seen what Congress makes of the shuffles in funding emphasis. Some Congressmen and Senators are deeply concerned that the present White House administration is not responsive to the needs of the United States and hold Frosch responsible as an appointee and representative of President Carter. Just one year ago ex-Apollo 17 astronaut Senator Harrison H. Schmitt expressed concern at the present attitude and said that he could not help feeling that "In spite of the great pronouncements of the so-called Administration space policy, that the Administration is once again lying to us, they're lying to the Congress, and they're lying to the American people ... whatever the OMB has sent us is a clear indication that the Administration is serious about a declining NASA budget ..."

During testimony on the 1980 budget, Schmitt developed an argument now boiling close to the surface in which he challenged the record of the present NASA leadership concerning new programmes to more effectively eploit the Shuttle. Several Committees that for many years have given strong support to the space agency suggest that NASA should plan now for new capabilities rather than rest back on the satellite launching role, intended as only one of its several capabilities.

SCHMITT "Doctor, what we are talking about in this Committee is a lack of vision. We're not arguing about so much the level of the budget but what the symptoms are within that which create the declining level of budget. There is no committment."

FROSCH "Senator, I think there is a committment. We're arguing about whether the current budget is right."

SCHMITT "There is no committment to the future of space in this country. There is a committment to complete the Space Shuttle; beyond that, there is no committment. I don't see one of any significance compared to the opportunities, compared to what other nations and other societies are going to be doing."

FROSCH "What it amounts to is that China is buying a couple of US satellites."

SCHMITT "What it amounts to is that the major competitor we have on this planet, that is the Soviet Union, is extraordinarily interested in their future in space, and I see no comparable interest in the administration of the United States."

In further testimony, Dr. Frosch clearly outlined for the Senate space committee his view that on the prospect for a manned Earth orbiting space station, "I can see it as useful for learning what it's useful for, but I don't think we have a demonstration of what we would do with it at this point." The NASA Administrator has expressed similar feeling about the possibility of using the Shuttle for space industrialization, the erection of large structures in orbit to survey the methods necessary for assembling antenna farms, solar power satellites, or materials processing facilities.

SOLAR MAXIMUM MISSION

NASA's dependence upon Space Shuttle, an uncertain reed at best because of development problems, came into sharp focus 14 February with the launch of a Solar Maximum Mission satellite, writes G. L. Harris.

It was the last planned launch of a scientific spacecraft on Delta or Atlas Centaur vehicles. Delta has carried 60 scientific missions for the space agency which is in its 22nd year.

"It was also the last payload for either vehicle funded entirely by NASA," Kennedy Space Center announced.

The three remaining launches in 1980 involve commercial or military payloads. NASA provides booster vehicles while users supply spacecraft and reimburse the agency for launch costs. Thereafter the Shuttle presumably will replace both Delta and Centaur although its initial flight has been delayed to 30 November 1980 at the earliest.

SMM rode a two-stage Delta with nine Castor IV solid rockets increasing first stage thrust because this was the heaviest Delta payload weighing 2,360 kg. The planned circular orbit was 574 km above Earth. NASA hopes to recover SSM from orbit on Shuttle Flight 15.

SSM will take solar measurements during 1980, the most active period of the Sun's 11-year cycle. Seven instruments will record solar flares and other activities in white light, ultraviolet, X-ray and gamma frequencies.

NASA has studied the Sun since 1962 with the launch of the first Solar Observatory followed by seven others. The primary scientific mission of Skylab, launched in 1973, involved measurements of solar characteristics in all frequencies from visible light to X-rays. In the Helios programme, a joint venture of the US and West Germany, two spacecraft penetrated outer fringes of the solar corona.

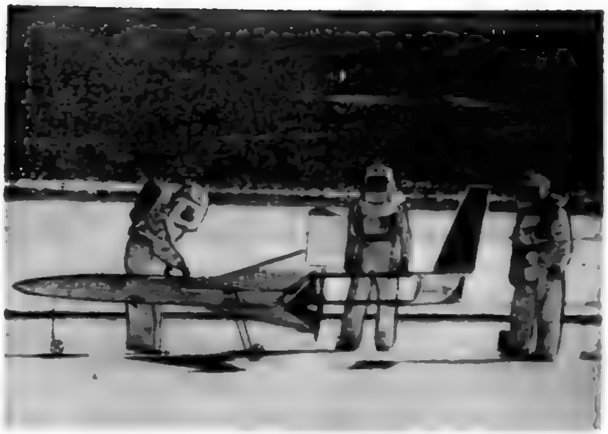
Solar flares are the greatest of transient disturbances, emanating from plage regions or "hot spots" on the surface. They can seriously affect Earth's magnetic field. Plasma clouds arriving a day or two after a flare seem to carry "frozen" magnetic fields producing geomagnetic storms, causing spectacular aurorae and disturbances in Earth's radiation belt.

The US maintains a solar "weather station" in Boulder, Colorado to watch for flares and warn affected interests.

Specific scientific objectives of the SSM include:

- to observe flare and flare-induced effects in the Sun's chromosphere, chromosphere-corona transition region and corona;
- to determine fundamental characteristics of solar plasma before, during and after flares;
- to study coronal evolution at solar maximum activity;
- to determine temperature and density structure of high energy flare plasma as a function of space and time
- to investigate the position, structure, and thermodynamic properties of hot thermal and non-thermal sources in flares;
- to investigate electron acceleration and very high temperature plasmas by observing high energy solar X-rays;
- to determine the spectral and temporal history of proton acceleration in flares from gamma ray lines.

Investigators and personnel of the Solar Forecast Center, plus guest investigators, work at Goddard Space Flight Center in Maryland. Nearly all SSM data are being transmitted directly to data reduction equipment operated by investigator teams. Goddard also transmits commands to the satellite.



"MINI SNIFFER". At NASA's Dryden Flight Research Center technicians service the hydrazine engine on the "Mini-Sniffer" research vehicle. The hydrazine engine, driving a pusher propeller, enables the "Mini-Sniffer" to fly at extreme altitudes and perform a variety of missions. A craft using the "Mini-Sniffer" technology is under consideration for future exploration of the planet Mars.

NASA

PERMAFROST ON MARS

Writing in the Soviet magazine *Priroda* ("Nature"), the Muscovite scientist Ruslan Kuzmin claimed that according to data collected by spacecraft, the planet Mars had a mantle of ice and frozen rock. The thickness of the layer containing ice on the Martian equator was 1.1 km. This thickness grew towards the poles where it reached 3.5 km. Below the ice mantle there were layers of ice with gas hydrate – a mixture of ice and carbon dioxide – followed by carbon dioxide and dry ice.

Kuzmin calculated that there was considerably more water on Mars than had been expected. It was possible that 100 times more water had been preserved in the permafrost than in the planet's polar caps. Changes in the climate of Mars or the penetration of molten magma from the planet's core into the upper layers could at one time have melted the permafrost and released the water and carbon dioxide gas. Traces of these events were observed in the Martian hollows, landslides and gullies.

Scientists under the guidance of Ruslan Kuzmin had built a model of Mars at the Geochemistry and Analytical Chemistry Institute in Moscow to illustrate these interesting planetary phenomena. *Julian Popescu*

GAMMA RAY SATELLITE

The Gamma Ray Observatory, a proposed new start in NASA's fiscal 1981 budget, is designed to explore sources of gamma rays in space – the most energetic form of radiation known.

The Earth-orbiting observatory, to be launched by the Space Shuttle in 1985, will carry instruments which will detect gamma rays in a variety of forms, very high energy gamma rays from pulsars, nuclear gamma rays and gamma ray bursts. The planned orbit is 250 to 300 miles.

Information returned is expected to provide a much deeper understanding of the nature of supernovas, pulsars, quasars and radio galaxies, the character of the universe at an early time, and the possible existence of antimatter in the universe.

Scientists also hope to learn more about the incredibly dense matter which makes up such objects as neutron stars.

The data may also shed more light on the nature of gamma ray bursts – erratic pulses of gamma rays that appear every month or so and flash across the Solar System. Their origin is a mystery.

Like X-rays, gamma rays are a form of electromagnetic radiation (as is ordinary light), but they have extremely high energy and correspondingly short wavelengths (less than 10^{-11} cm). At maximum strength, a gamma ray unit packs several million times as much energy as a comparable unit of visible light.

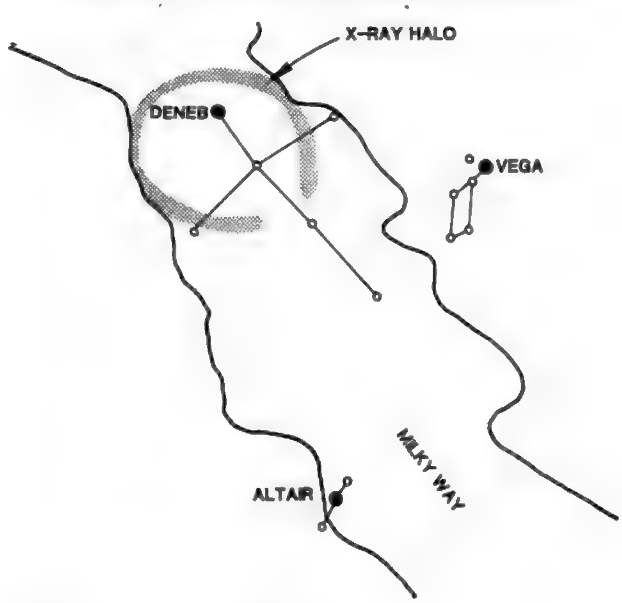
Unlike X-rays, however, which are typically emitted by hot gas, gamma rays are believed to come from the core of the phenomenon, produced by special nuclear processes. Gamma ray astronomy allows scientists to investigate these special processes.

Until recently all astronomy observations were of atoms, ions and molecules, and their emissions. Gamma rays were recognized after World War II as an important aspect of space research, but work in this field was slow.

A long program of balloon research proved rather disappointing, with only hints that gamma ray sources were being detected.

Then a small experiment on an Orbiting Solar Observatory detected the first certain gamma rays. This gave scientists the confidence to launch in 1972 the Small Astronomy Satellite-2 with a small detector for very high energy gamma rays. This spacecraft, along with the European spacecraft COS-B (1975), and the first High Energy Astronomy Observatory, provided the basic data which will be exploited by the more powerful Gamma Ray Observatory.

THE X-RAY HALO OF THE NORTHERN CROSS



SPACE SUPERBUBBLE

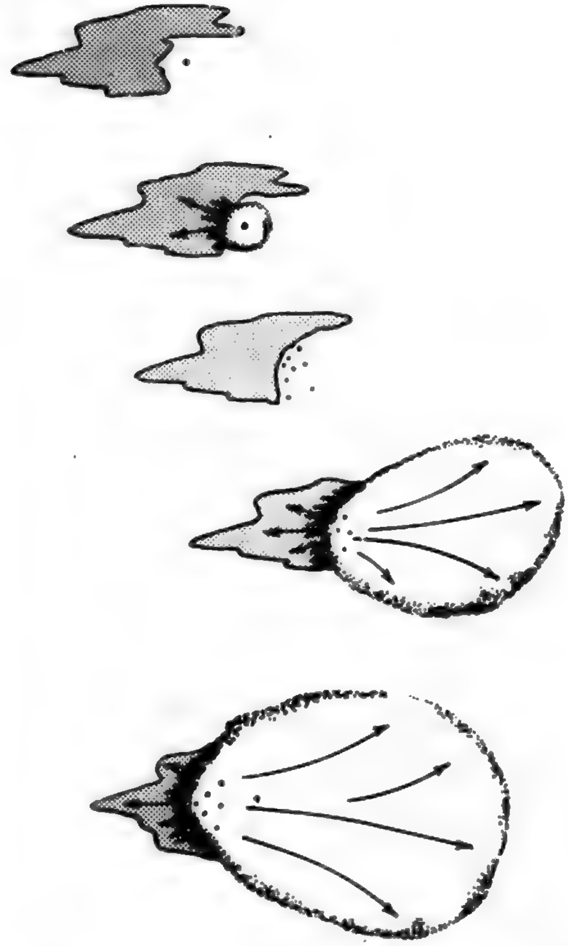
A superhot, superbubble of gas, apparently confined to a gigantic, glowing ring or shell some 6,000 light years away from Earth and some 1,200 light years in diameter, has been discovered. It is centred in the prominent summer constellation Cygnus, the Northern Cross.

The discovery was made from satellite data by Dr. Webster Cash, Laboratory for Atmospheric and Space Physics at the University of Colorado, Boulder, and his co-investigator, Dr. Philip Charles, Space Science Laboratory, University of California, Berkeley. They used X-ray data from NASA's Earth-orbiting High Energy Astronomy Observatory 1.

Dr. Cash reported that the sphere contains enough superheated gas at 2 million degrees Celsius (3.5 million degrees F), to create 10,000 new stars like our Sun. Its energy output is equal to 10 times the amount of the entire energy emitted by our Sun since its formation some 5,000 million years ago. There are very few astrophysical processes in the Galaxy which are capable of supplying this much energy. The most powerful explosion known to astronomers is that of a supernova, an exploding star, but a supernova releases only about 3 per cent of the energy needed to make the superbubble.

What puzzles scientists is finding an answer to how this huge amount of energy got locked up in this gigantic halo in the first place. Dr. Cash thinks there may have been a series of explosions of supernovae in the region over the past three million years, perhaps anywhere from 30 to 100 which, in sequence, together created the superheated superbubble.

Here's how it may have happened, says Dr. Cash: A huge cool gas cloud, measuring 800 by 3,000 light years, known as the Great Rift of Cygnus can be seen obscuring the Milky



Five steps in the evolution of a "superbubble" *Top to bottom*, Cloud and star; star becomes supernova and shock wave strikes cloud; new stars are formed from cloud; new stars become supernovae and create the bubble, which starts to inflate; and finally, as more stars are formed, the superbubble grows even larger.

NASA

Way in Cygnus on a dark night. This dark cloud has enough material to make five million stars and lies right next to the observed superbubble. In fact, it obscures the central part of the bubble as seen from Earth.

About three million years ago a supernova exploded and impacted the gas cloud with part of the star blowing into interstellar space. As the force of the explosion moved through the cloud, the compression caused the gas to coalesce about 100,000 years later, forming a group of perhaps 1,000 stars of which number about 10 would become supernovae. Supernova stars have a lifetime of only about one million years.

These 10 stars would explode, in turn, pushing the gas cloud back farther and causing more stars to form along its edge as the compression on the cloud continued. At the same time, the force of the explosions away from the cloud caused a sweeping effect on interstellar space making a shell or bubble of superheated hydrogen material that became the immense superheated, superbubble we see in X-ray data today.

Dr. Cash said these chains of star formation are a major mechanism for making new stars. "The Sun may well have been formed at the edge of a similar bubble," he said.

The reason the huge halo was never spotted before is because, Dr. Cash says, "it flows so energetically that it cools through emission of X-rays instead of more normal emissions that can be seen in the optical or infrared regions of the spectrum." The hotter a substance is the shorter its radiation wave length.

Although parts of it had been seen before in brief X-ray glimpses, no one knew what was being observed. One part, for example, was thought to be a supernova remnant, while another part was believed to be hot gas escaping from the Galaxy.

Because of its large size, the bubble or halo, was not seen in its entirety until it could be picked up in the X-ray sweep provided first by the High Energy Astronomy Observatory launched in August 1977. The spacecraft burned up as it re-entered the Earth's atmosphere in March 1979 after accomplishing its mission.

SUCCESS OF ULTRAVIOLET EXPLORER

The outstanding performance of the International Ultraviolet Explorer (IUE) satellite, which completed two years' of operation in January, has been widely praised by the scientific community. A joint venture of the UK Science Research Council, the European Space Agency and NASA, the orbiting observatory has been used by scientists from many countries to observe a wide range of celestial objects in the UV spectrum from high above the Earth's atmosphere. Ground observatories are prevented from making such studies because the atmosphere absorbs UV radiation.

SRC provided the ultraviolet sensitive television cameras and image processing software. ESA provided the solar arrays and the European ground station near Madrid, and NASA supplied and launched the spacecraft, and operates the American ground station in Maryland.

The satellite was originally designed to have a minimum life of three years which is now confidently expected to be considerably exceeded. That is fortunate because the observing time already requested by astronomers has been more than double that available. All three sponsoring agencies have decided to continue operating the satellite as long as is justified by the scientific return.

The satellite has pioneered a new method of operating a space telescope: astronomers visit a ground station to examine images relayed from IUE and they can direct the telescope in the same way as they would at a ground-based optical observatory. More than 500 scientists from 20 countries are studying 12,000 ultraviolet spectra (over the wavelength range 115 nm to 320 nm) of planets, stars, the interstellar medium and galaxies. Because the strongest characteristic light emissions of many of the commonest atoms and ions lie in the ultraviolet, a wealth of information can be obtained about the chemical composition and physical state of astronomical objects.

Although the IUE telescope is small (45 cm diameter) by comparison with modern ground-based optical telescopes, observing efficiency is high because outside the Earth's atmosphere there are no problems of cloudy nights and long exposures can be made with minimal interference from background light. Using 14-hour exposures, faint spectra of distant quasars (magnitude = 17) have been obtained in a wavelength region that gives theoreticians new information about these enigmatic objects.

Using the IUE, astronomers have discovered that stellar winds – the process by which material is driven away from a star mainly by radiation pressure – exist in types of hot star not previously known to exhibit this phenomenon. Detailed data have been obtained on the material in the chromospheres and coronae of cool stars. New results show how the shockwave from an old supernova interacts with the interstellar material. Gas forming a hot coronal halo around our galaxy has been discovered and it is believed that other galaxies also have such a halo. Ultraviolet studies have been made of X-ray binaries which are thought to comprise a normal star orbiting with an exotic object which could be a white dwarf, a neutron star or a black hole. IUE observations have also been made of distant active galaxies, including quasars, which are known to emit vast amounts of energy.

Finally, the flexibility of operating IUE has allowed unexpected phenomena (such as the explosion of novae and supernovae or the approach of a bright comet) to be observed and followed immediately after their discovery.

"EINSTEIN" FLIES ON

NASA's High Energy Astronomy Observatory 2, originally scheduled to end operations after one year in Earth orbit, will continue to search the skies for information about such objects as quasars, pulsars, exploding galaxies and black holes. Officials decided that the many significant findings attributed to the spacecraft – which carries the largest X-ray telescope ever built – warranted an extension of its space science mission beyond the projected lifetime of 11 months.

"The performance of the observatory has been excellent throughout the first year of the mission," said Dr. Thomas A. Mutch, NASA Associate Administrator for Space Science. "The operation of the scientific instruments has met or exceeded all expectations."

The instruments continue to operate satisfactorily. A solid state spectrometer, which performed exceptionally well, has depleted its cryogens, and ceased operating, as expected.

Among the most significant new findings from the observatory (nicknamed Einstein by scientists who provided the instrumentation on board) are the following:

- The X-ray observation of more than 60 known quasars, ranging from relatively nearby to the most distant objects known, and the discovery of more than a dozen previously unknown. These findings open an important new approach to the study of the nature and evolution of these objects.
- The determination that a substantial fraction of the extragalactic radiation background may be due to scattered individual sources. This finding has important consequences regarding the question of an open or closed Universe.

- The surprising absence of hot neutron stars at the centres of supernovae (exploding stars), which requires new cooling mechanisms to be postulated for the remaining core of a supernova explosion.
- The discovery that the coronas of certain main sequence stars emit X-rays with greater intensity than had been predicted by current theories. This finding requires a substantial rethinking of energy-transport mechanisms in stars.

A continuing activity with the observatory is NASA's Guest Investigator Programme in which scientists use data from the spacecraft for studies not directly related to the planned objectives. Since the launch of the observatory, about 400 guest investigator proposals have been received by NASA. They were submitted by more than 80 groups from the United States and other countries, including Great Britain, France, Germany, Italy, USSR, India and Japan.

The Einstein Observatory is the second in a series of three spacecraft designed to survey the sky for X-ray, gamma-ray and cosmic-ray sources.

The first observatory, launched in 1977, conducted an all-sky survey and mapped about 1,500 X-ray sources, many of which were subsequently correlated with visible objects in the sky. It also measured, for the first time, the temperature of the uniform high energy X-ray background. Many scientists believe these X-rays originated from a universal hot plasma thought to constitute a major fraction of the mass of the Universe.

The third high energy observatory, launched last September, is conducting an all-sky survey of cosmic and gamma rays, but at higher energies and from a higher orbital inclination than the first observatory.

FLIGHT MODEL

Earlier this year NASA signed a contract to purchase from ESA a flight model of Spacelab, the European manned space laboratory. This is in accordance with the terms of the Memorandum of Understanding concluded in 1973 between NASA and ESA which provided for the supply of a Spacelab to NASA and for the purchase by NASA of a second one. This order was converted by ESA on 30 January into a contract with European industry.

The price agreed with the Spacelab prime contractor, the German firm ERNO, amounts to 117.1 MAU (at 1979 economic conditions and the 1979 exchange rate*). The contract provides for the supply to NASA of a fully-equipped pressurized module, five instrumentation pallets, and various associated equipments and spares. These items will be supplied to the United States in deliveries phased over the period from October 1981 to April 1984.

Spacelab is an orbital laboratory which is to be flown within the main element of the NASA Space Shuttle - the Orbiter - to which it will remain attached; it may be assembled in various configurations: pressurized module only, pressurized module plus instrumentation pallet(s), or instrumentation pallets only, and may be manned when the pressurized module is used. It can carry out missions of at least a week in orbits ranging between 200 and 900 km altitude. After each mission the Orbiter returns to the Earth and receives a new payload which can either be a further Spacelab or other equipment to be carried into space.

The first Spacelab mission is at present scheduled for April 1982. It will be a joint ESA/NASA mission for which Spacelab will carry a mixed payload shared equally between the two agencies. There will be two payload specialists on board the Spacelab, one European and one American.

Spacelab is being built for ESA by an industrial team comprising nearly forty firms from ten European countries (Germany, Belgium, Denmark, Spain, France, Italy, Netherlands, United Kingdom, Switzerland, Austria), the project leader being the firm of VFW-FOKKER/ERNO (Germany).

* *MAU: million units of account. 1 AU = 1.23$.*

BRITAIN'S AMATEUR SPACECRAFT

The National Aeronautics and Space Administration has formally agreed to launch Britain's first amateur spacecraft, UOSAT. It will form a secondary payload on the launch of the Solar Mesosphere Explorer mission from the Western Test Range in California, at present scheduled for 30 September 1981. The Thor-Delta launch vehicle is expected to place UOSAT in a circular polar orbit at a height of 530 km. The launch opportunity is being provided by NASA because of the satellite's potential contribution to space science education and to the investigation of radio propagation phenomena.

UOSAT is being built at the University of Surrey, in close collaboration with the international Amateur Satellite Corporation (AMSAT), the Amateur Satellite Organization of the UK (AMSAT-UK) and the Radio Society of Great Britain. Much support is being given by Britain's electronics, telecommunications and space industries.

The spacecraft's purpose is primarily educational. It will carry a series of high-frequency radio beacons, enabling individual radio amateurs and science groups in schools and colleges to study the changing effects of the ionosphere on radiowave propagation. Further experiments of interest to schools are in the planning stage and will be announced when their design details are confirmed.

An additional experiment likely to cause considerable scientific interest is a three-axis magnetometer. This should make possible a detailed study of the magnetic fields of the Earth's polar regions. The instrument will be built by an amateur radio enthusiast, Mario Acunia, at the Goddard Space Flight Center, and will be based on the very successful instrument he built for the Voyager mission to Jupiter.

Steady progress with the project as a whole is being made as follows (work carried out at the University of Surrey unless otherwise stated):

- The overall system design has been confirmed.
- The structure of the spacecraft has undergone redesign and structural analysis (British Aerospace Dynamics Group).
- A survey has been made to determine the most suitable method of stabilizing the spacecraft and of keeping it the right way up.
- A lower power microcomputer system has been constructed to "breadboard" stage (Mike Stubs, Ferranti).
- A telecommand receiver has been constructed to "breadboard" stage and has operated continuously for three months without problems.
- A first prototype radio beacon, operating at 145 MHz, has been constructed.
- A number of spare solar panels from the UK-6 project have been donated (Science Research Council).

One of the limitations in building an unmanned spacecraft is that there is no way of repairing components which go wrong during or after launch. To avoid such problems as far as possible, spacecraft are built in three stages:

1. *"Breadboard" Stage.* Each of the proposed electrical and electronic systems in the spacecraft is first constructed as a circuit on a flat board. The purpose of this is to test each circuit to check that its performance matches the original design specification. This is known as the "breadboard" stage because in the early days of electronics, amateur enthusiasts sometimes used the family breadboard as a base on which to fasten the various components.
2. *Engineering Model.* Each of the systems and experiments is then built in its final form and everything is assembled on the spacecraft chassis. The engineering model is, to all intents and purposes, a finished spacecraft but it is not normally launched. Instead it is subjected to heating, freezing, vacuum, vibration and other forms of maltreatment in order to trace any weaknesses.
3. *Flight Model.* This is a repeat of the engineering model, incorporating improvements as a result of experience gained in testing and ground operation. It also goes through extensive tests, though not to the rigorous extent suffered by the engineering model. This is the version that actually goes into orbit, though if it fails completely (as a result of the launch vehicle failing to go into orbit, for example) the engineering model can be used as a successor if an alternative launch opportunity exists.

The three phases of construction overlap considerably in time. At present the "Breadboard" stage for UOSAT is planned to be completed by August 1980, the Engineering Model by December 1980, and the Flight Model by August 1981.

NEW DEVICE DETECTS CANCER

An instrument that makes use of space technology is being evaluated as a detector of cancerous tumours in the human body. Developed at NASA's Langley Research Center, Hampton, Virginia, the device – called a microwave applicator – is being tested at the Eastern Virginia Medical School at Norfolk General Hospital.

The device which also will be tested for use in the treatment of cancerous tissue by heating a tumour to destroy cancer cells, has demonstrated already that it can locate tumours in 14 known cancer patients and has even found a cancerous site in one patient that was undiscovered by conventional techniques.

The microwave applicator's prime advantages are that it does not emit radiation, is used outside the body and should become relatively inexpensive if mass-produced.

If the instrument proves itself after an extensive series of hospital and laboratory tests, it could become standard equipment in doctor's offices. Patients could be quickly and easily tested for many forms of cancer, just as they are tested routinely now for heart problems with an electrocardiogram machine.

The microwave instrument contains a sensitive radiometer that can measure temperature variations of less than 0.1 degree Celsius (0.2 degree Fahrenheit). Because cancerous tissues are hotter than surrounding normal tissue, they are thus detectable by the applicator.

The applicator also can detect heat differences much deeper in the body than conventional infrared thermography. Infrared thermography techniques are limited to detecting tumours near the skin's surface.

The next step in proving the instrument will begin early in 1980 when researchers at the Norfolk Medical School and at the Medical College of Virginia in Richmond test the device's ability to treat cancer in large laboratory animals.

The treatment method will involve microwave heating of a tumour area to destroy cancer cells. Temperatures higher than 42 C (107.6 F.) are considered lethal to cancerous tissue.

Tumours have a poorer vascular system (fewer blood vessels) as compared to healthy tissue and contain more fluid. Researchers believe that heat from the microwave system will heat a tumour faster than the surrounding tissue because of the higher moisture content and the tumour will stay hotter because there are fewer blood vessels to carry the heat away.

The project began when a Langley researcher suggested that Langley's microwave experts, who normally work on satellite communications and other space projects, should get involved in some way with using microwave techniques to detect and treat cancer.

After preliminary research and development, Microwave Associates, Inc., of Burlington, Massachusetts, which has worked with NASA for several years on aerospace projects, was asked to develop and build the instrument. Total funding to date, from the NASA Technology Utilization Program, has amounted to less than $47,000.

MODEL "T" SOYUZ

The Soviet Union launched a Soyuz-T, a new type of unmanned Soyuz transport spacecraft from the Baikonur Cosmodrome on 16 December 1979. The spacecraft was put into an initial orbit of 201/232 km×51.6°, 88.9 min. Three days later the new transport spacecraft linked up with the Salyut 6 space station, writes Gerald L. Borrowman. The docking of the Soyuz-T was the 16th link-up of a spacecraft with the Salyut 6. The Soviet news agency *Tass* reported that Salyut-6 was "actively functioning after 26 months of operations." The Salyut 6 space station has been unmanned since cosmonauts Vladimir Lyakhov and Valery Ryumin returned to Earth on 19 August 1979 after setting a new space endurance record of 175 days and 36 minutes.

Soyuz-T is described as having onboard a digital complex which allows ground control to monitor the execution of manoeuvres, the condition of all systems and other current information. Soyuz-T is testing a new propulsion system which is similar to the joint propulsion unit of the Salyut 6 space station. The design of Soyuz-T incorporates the manned transport features of the basic Soyuz and cargo-carrying capabilities of the Progress unmanned transports. Soyuz-T is reported to be capable of carrying a three-man crew.

Testing of the Soyuz-T apparently began on 29 November 1976, when Cosmos 869 was orbited for an 18-day mission. A second test, Cosmos 1001, was given an 11-day trial in orbit from 4–15 April 1978. The most recent test was Cosmos 1074 from 31 January to 1 April of last year, a 60-day mission, which may be a demonstration of the spacecraft's orbital endurance.

ASRC EXPANSION PLANS

The Alabama Space and Rocket Center in Huntsville, Alabama, has unveiled ambitious plans that would vastly expand the size of its present facilities and add many new attractions to cater to the millions of visitors expected in the next decade. The many BIS members who have visited the site during organised tours of the USA will already be aware that the present display is extremely impressive.

Director Ed Buckbee said plans call for enlarging the centre's displays by inclusion of a Space Shuttle in launch configuration with its two solid rocket boosters (SRBs) and related hardware; creating a youth science camp; inaugurating an energy information centre; and adding a planetarium, Saturn service tower and a multitude of recreational facilities.

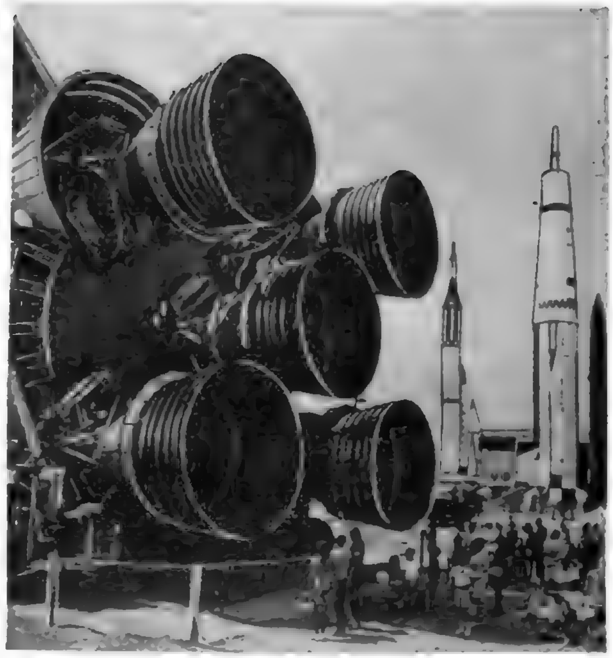
All these additions to the existing 35-acre centre would be built on some 380 acres of adjacent land currently part of the Redstone Arsenal.

Already the largest rocket and space museum in the world and containing more than 1,500 pieces of rocket and space hardware valued at over $30 million, the ASRC also serves as a major repository for the Smithsonian Institution's National Air and Space Museum and has on loan more than 300 major historic artifacts.

Stressing the ASRC has been self-sustaining since it first opened its doors in 1970, Buckbee appealed for joint government and industry support to raise the more than $11 million needed for expansion over an eight-year period.

The ASRC hopes to raise more than $5 million for the first phase, scheduled for FYs 1980-1982, with the private sector being asked to contribute $1.5 million. Local governments and state grants are expected to make up the rest.

Based on current out-of-state attendance figures, Buckbee estimates the projected expansion will draw 500,000 visitors annually by the mid-80s and 750,000 by the end of the decade, generating $25 million for the centre, and contributing $60 million to the area economy and $5 million to local taxes.



SATURN 5 exhibit at the Alabama Space and Rocket Center in Huntsville, Alabama. Consuming 5,000 gallons of liquid propellants, the five Rocketdyne F-1 rocket engines would generate 160 million horsepower. In the Apollo programme engines of this type lifted American astronauts during the first 40 miles (64 km) of their journey to the Moon.

ASRC

BRITAIN'S SPACE EFFORT

Britain's progress in the commercial world of communications satellites has improved by leaps and bounds over the past 18 months thanks to contracts received from the European Space Agency. The recent appointment of British Aerospace Dynamics Group as prime contractor for the L-Sat programme follows the receipt of contracts worth £130,000 for five European Communications Satellites (ECS) and three MARECS satellites for which BAe Dynamics Group also has prime responsibility. These contracts would appear to confirm British Aerospace as the most capable and experienced communications satellite design and construction team in Europe.

L-Sat – a large communications satellite about twice the size of ECS and several times more powerful – is fully competitive with the most advanced projects in the United States. It is scheduled to be placed in Clarke (geostationary) orbit in 1984 to provide communications coverage of Europe. Two L-Sats are to be built, one to be held as a spare. As well as being able to transmit TV broadcasts at high power for direct reception by individual houses equipped with small rooftop antennae, L-Sat will be capable of carrying a considerable volume of telephony and data traffic.

Definition of the satellite and its communications package includes a requirement that launching can be carried out either by the ESA Ariane or the NASA Space Shuttle.

Although being developed initially as a European project, derivatives of L-Sat could very well interest other countries interested in establishing their own regional satellite systems. With 10 kW of power available to the payload, they would have a large multi-mission capability.

TELECOMMUNICATIONS IN THE YEAR 2000

Demand for telecommunication services within the United States, with an increasingly prominent role for space satellite video and data communications traffic, is expected to grow fivefold by the turn of the century, according to recent studies.

The studies, conducted for NASA by the US Telephone and Telegraph Corporation, show that demand for conventional voice services – message-toll service and private-line traffic – will continue to predominate. By the turn of the century, as much as one-fourth of all long-distance voice traffic may be carried by satellites, as well as half of all data and video traffic.

The studies were done in conjunction with NASA's recently announced decision to renew programmes directed at advanced communications satellite research and technology. Primary emphasis is on developing technology needed to open the 20/30 gigahertz (GHz) frequency band for commercial use during the next two decades in a cost-effective and spectrum-conserving manner. The band has not to date been used in the USA.

The recently concluded studies show that by the early 1990s growing demand for long-distance telecommunications services will have saturated the nation's existing domestic satellite capacity in the bandwidths at 4-6 GHz (Ku-band). To accommodate this expected rapid growth in demand, more versatile satellites that have higher capacity and operate in the 20/30 GHz band, as well as in currently used bands, will be required.

A major attraction of the 20/30 GHz band, called Ka-band, is the broad frequency range allocated to communications satellite use – five times the band allocated at C-band or Ku-band. Using the Ka-band, advanced technology satellite systems would have message capacities of 50 to 100 times those operating in the C-band.

The studies conclude that most data-services traffic will originate and end at terminals served by computers, with executive videoconferencing expected to become a partial substitute for business travel by the year 2000. By then, 90 per cent of all telecommunications traffic will require real-time, or instantaneous service. The remaining 10 per cent, such as electronic mail delivery, will be non-real-time needs.

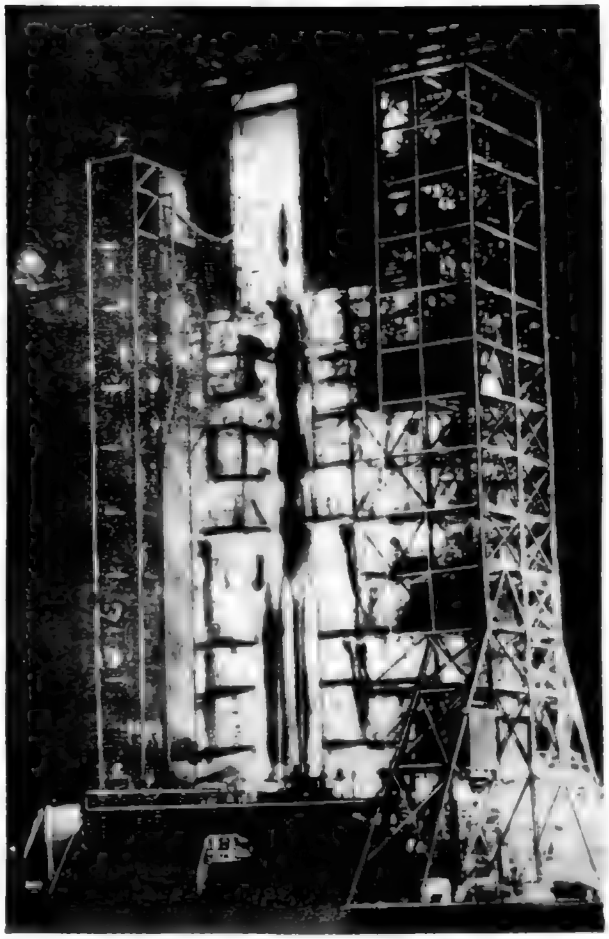
DELTA LAUNCHES TO CONTINUE

NASA is prepared to maintain an expendable launch vehicle capability at the Eastern Space and Missile Center, Florida, as a backup to the Space Shuttle during the transition to full Space Transportation System operations. In doing so, NASA will use the standard 3910 version of the Delta launch vehicle, which can place spacecraft of up to 2,400 lb (1,100 kg) into a geosynchronous transfer orbit. Commercial users of these Deltas will be charged $22 million per launch in the early phases of the transition period.

NASA also is planning to launch several payloads in 1981 from the Western Space and Missile Center, California, before the Space Shuttle is expected to become operational there. Included will be the Landsat-D Earth resources spacecraft scheduled for launch in early 1982.

Landsat-D and its backup, however, require a Delta vehicle with payload capability above that of the 3910 version. This increase in Delta capability will be achieved by augmenting an existing Delta second stage engine with an improved injector recently developed for the Air Force by Aerojet General Corporation, and by using larger second stage fuel tanks, also available from Aerojet. Uprated McDonnell Douglas Delta launchers, to be called Delta 3920, will have a payload capability up to 2,750 lb (1,250 kg) for a geosynchronous transfer orbit. The development cost of uprating the Delta second stage is estimated at from $7.5 to $9 million. The vehicle hardware cost per launch will be about $2.5 to $3 million more than that of the standard Delta 3910.

Last October, NASA asked potential commercial users if they would be interested in sharing the $7.5-9 million development cost of the uprated vehicle. This offer was aimed primarily at commercial users with large geosynchronous orbiting communications spacecraft who are already scheduled on early Space Shuttle operational flights, but who might want a backup launch alternative in the event flight schedule changes or delays affect Space Shuttle operations. Telesat of Canada agreed to fund about 20% of the costs, with NASA paying the remainder. If other commercial users decide to reserve a backup Delta 3920, they will be charged a share of the total development costs while the Telesat and NASA share will be reduced proportionately.



DELTA BOOST. Preparations for the launch of the Solar Maximum Mission (SMM) satellite continue into the night at the Kennedy Space Center, Florida. The Delta launch vehicle has nine Castor IV solid propellant rockets to lift its heaviest payload to date (see page 282). The satellite, launched on 14 February 1980, entered an orbit of 566×569 km inclined at 28.51 deg to the Equator.

NASA

SATELLITE ORBITS WHICH REPEAT

By Phillip S. Clark

Introduction

When planning a satellite mission it is generally desirable to use an orbit which allows the ground track to repeat after a given number of orbits. In this article the writer will described briefly the "repeater" orbits which the Soviet Union has used in its manned and unmanned space programme.

Method Used

The condition that a satellite ground track will repeat after a given number of orbits – when the effects of orbital decay are neglected – is given by the following equation:

$$\frac{360\cdot 9856.n.P.}{1440} + \frac{540.n.J_2.6378^2.\cos(i)}{a^2.(1-e^2)^2} - 360(INT)=0$$

where we have

- n   number of orbits after which the ground track repeats.
- P   orbital period, minutes.
- J_2 constant of the Earth's gravitational potential, 0.00108.
- i   orbital inclination.
- INT   a suitable integer.
- a   semi-major axis of the orbit, km.
- e   orbital eccentricity.

Of course, by Kepler's Third Law the semi-major axis of the orbit is a function of the orbital period.

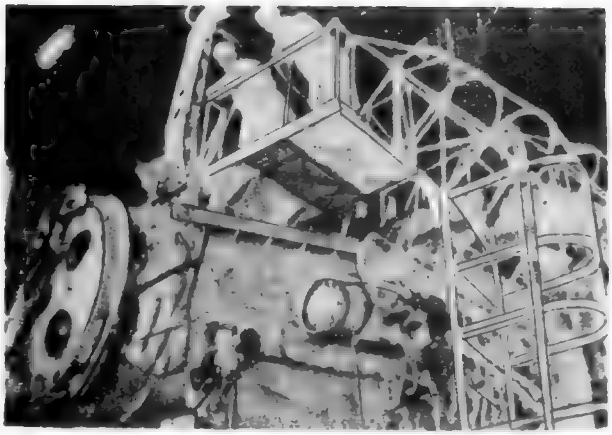
As it stands, the above equation cannot be solved analytically, so one has to resort to successive numerical approximations to find the orbital period when n, i and e are specified. In the preparation of this article the writer used the programmable Texas Instruments TI-59 calculator to iterate on P when an initial value of the period could be estimated. The calculator gave the results to three decimal places for the orbital period (here the results are rounded to two decimal places) and one decimal place for orbital altitude (here rounded to the nearest integer).

The Table given shows the results for both the manned and unmanned programme orbits which were considered. Of course, it would be impossible to review all the unmanned programmes, and here the data is given only for certain flights which have used the A- (Sapwood) and C- (Skean) class launch vehicles. The unmanned flights will not be commented on further, although the next section will review the man-related missions.

Man-Related Programmes

The primarily military orbital stations Salyuts 3 and 5 have used an orbit close to the 63 orbit repeater, while the civilian Salyut 4 and 6 missions have flown in the 31 orbit repeater slot. In July 1979 the unmanned Progress 7 was used to boost the Salyut-6/Soyuz-34 complex into the 46 orbit repeater slot.

The other two orbits listed as being "man-related" have not yet been used on a manned flight, but unmanned flights which are "obviously" (?) man-related have used them. Cosmos 869-929-1001-1074 have used the 78 orbit repeater slot, while Cosmos 929 manoeuvred into the 91 orbit repeater slot some months after its launch. It is possible that the latter orbit might see service when the Soviets introduce a more permanent orbital complex than Salyut 6.



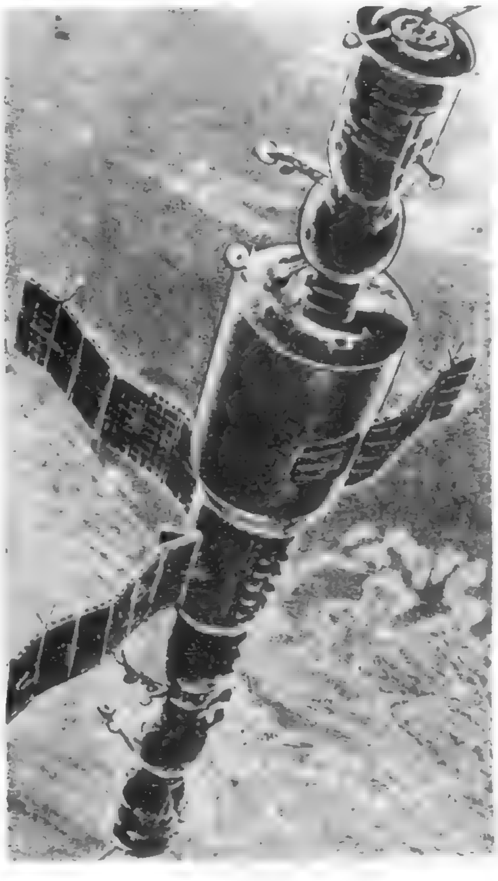
Preparation of the Salyut 6 space station during the summer of 1977. The launch took place at the Baikonur-Tyuratam cosmodrome on 29 September.

Theo Pirard

Summary of Repeating Orbits.

Incl o	e	n	Period min	Altitude km	Flights
(1) *Manned Programme*					
51.6	.001	63	89.85	260–274	Salyut 3/5
51.6	.001	78	90.74	304–318	Cosmos 869/929/1001/1074
51.6	.001	31	91.35	334–347	Salyut 4/6
51.6	.001	46	92.37	384–398	Salyut 6 (with Progress 7)
51.6	.001	91	93.42	435–449	Cosmos 929
(2) *Unmanned Programmes – Near-Circular Orbits*					
50.6	.001	15	94.46	486–500	Intercosmos 11 & others
50.6	.001	44	96.68	593–607	Cosmos 546, Ariabat
56.0	.001	44	96.83	600–614	Cosmos 103/151/236
65.8	.001	59	96.56	587–601	Cosmos 394/803/880
74.0	.001	15	95.19	521–535	Cosmos ferret
74.0	.001	43	99.68	736–750	Cosmos navigation
74.0	.001	85	100.86	792–807	Cosmos store-dump
74.0	.001	41	104.60	968–983	Cosmos navigation
74.0	.001	25	114.46	1423–1439	Cosmos octuple communications
81.2*	.001	59	97.06	611–625	Meteor-1, Cosmos
81.2*	.001	14	102.30	860–875	Meteor-1/-2
82.5**	.001	44	97.66	640–654	Cosmos 1025/1076
83.0	.001	91	94.44	485–499	Cosmos 900, Intercosmos 17
83.0	.001	41	104.60	968–983	Cosmos navigation
(3) *Unmanned Programmes – Eccentric Orbits*					
50.6	.015	91	93.39	338–543	Cosmos 1065/1112
56.1	.041	15	94.62	218–782	Cosmos 38-40
62.8*	.737	2	717.74	606–39747	Molnia-1/-2/-3, Cosmos
65.9	.071	49	116.61	967–2090	Cosmos 839/909
74.0	.034	91	94.13	243–710	Intercosmos 12
74.0	.034	86	99.67	501–985	Intercosmos 19
74.0	.083	14	102.07	256–1457	Intercosmos 10
74.0	.102	41	104.59	225–1725	Cosmos 378
74.0	.133	25	114.44	392–2469	Oreol 1
82.9	.096	41	104.86	281–1695	Intercosmos 13

Notes
1. The manned flights could use either the A- or D- class (Sapwood or Proton) launch vehicles to the orbits indicated.
2. Unmanned flights used the C-class vehicle, other than: * A-class vehicle; ** F-class vehicle.



Artist's impression of Salyut 6 with a Soyuz ferry docked at each end.

Theo Pirard

TILING THE SHUTTLE

By Kenneth Gatland and Stephen Smyth

One of the biggest problems holding up the first flight of the Space Shuttle "Columbia" at Cape Canaveral has been the task of applying the "second skin" of silica thermal tiles designed to protect the spacecraft from burning up when it re-enters the Earth's atmosphere. The method of applying the tiles, each of which has to be specially contoured to match the precise shape of the vehicle, has turned out to be more difficult, time-consuming and costly than expected. It is doubtful if the problem will be approached in quite the same way again.

Earlier this year NASA requested from private industry proposals for a design study of alternative thermal protection systems. Although the results will not affect present orbiter vehicles, promising alternatives will be considered for later application.

The study will include evaluation of such types of thermal protection systems as metallic and reinforced carbon-carbon concepts. It also will assess potential benefits and problems that might arise from alternative thermal protection concepts; establish guidelines to cope with varied loading conditions and handling, inspection and maintenance, and identify deficiencies in present technology that may require further research and development.

The present ceramic system (illustrated here) was selected in the 1970's as the best then available.

KENNEDY SPACE CENTER. A technician prepares an exact mould of a Thermal Tile for "Columbia", the first Space Shuttle. The mould will then be sent to California where the real tiles are being produced.

High and low technology exemplified in the preparation of one of the Thermal Tiles for testing before it is finally bonded to "Columbia".

WHITE HOT, AND FRESH FROM A 2300°F OVEN, the glowing cube provides the only illumination in these photographs as a technician holds it in his bare hands without injury. The demonstration illustrates the remarkable speed with which heat is cast off by a unique silica insulation that Lockheed Missiles & Space Company manufactures for the Space Shuttle. The company makes nearly 31,000 "tiles" of the material for each spaceplane, enough to cover all the underside and portions of the upper wings, fuselage and tail. Expected to survive at least 100 flights with minimum maintenance, the insulation is meant to protect the Shuttle orbiter from 2300°F (1260°C) re-entry temperatures. Photo at left was taken less than 10 seconds after the cube's removal from the oven; at right, less than 30 seconds from the oven, the cube's edges reach room temperature and turn grey while its interior remains red hot.

Lockheed Missiles & Space Co.

Below, inspectors check the bonding of two of the Thermal Tiles to part of "Columbia". Certain parts of the Shuttle have been removed to make the bonding job easier. Tile testing is being carried out in one of the two Orbiter Processing Facilities; the other houses "Columbia".

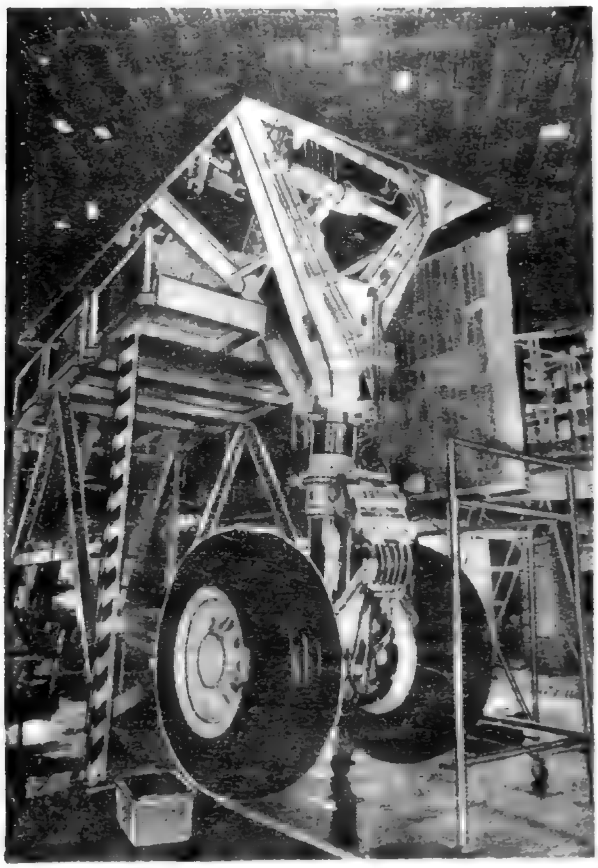
All KSC photos: Stephen Smyth

Dick Young, a member of the Public Affairs Staff at KSC, holds a Thermal Tile of the type at present being bonded to the first Space Shuttle.

Left, a Thermal Tile in one of the special containers used to carry it from one location to another. After testing, it will be fixed to the first orbital Space Shuttle.

Left below, an impressive view of the undercarriage on the starboard wing of "Columbia", seen here in the Orbiter Processing Facility in April 1980.

The partly completed Tiled Crew Hatch of "Columbia" which has been removed to make bonding easier.



35th ANNUAL GENERAL MEETING

THE BRITISH INTERPLANETARY SOCIETY

NOTICE IS HEREBY GIVEN that the 35th ANNUAL GENERAL MEETING of the BRITISH INTERPLANETARY SOCIETY Limited will be held in the Tudor Room, Caxton Hall, London, S.W.1. on Thursday 18th September 1980 at 19.00 hours precisely, for the transaction of the business specified in the Agenda below.

AGENDA

1. Report of the Society's Affairs for the year to 31st December, 1979.
2. To receive the Society's Balance Sheet and Accounts for the year ended 31st December, 1979, and the Auditors' report thereon.
3. Appointment of Auditors.
4. To elect four Members of the Council of the Society. In accordance with article 15 the following Members of the Council will retire at the Meeting.

   Dr. E.J. Becklake, G.J.N. Smith, A.T. Lawton, C.R. Turner.
5. General Discussion.
6. Any other business.

By Order of the Council,
L. J. CARTER,
Executive Secretary.

A member who cannot be personally present at the meeting may appoint by proxy some other person, who must be a member of the Society, to attend and vote on his behalf, subject, however, to the proviso that a proxy cannot vote except on a poll.

BRITISH INTERPLANETARY SOCIETY LIMITED (BY GUARANTEE)

REPORT OF THE AUDITORS

As more fully explained in Note 3 subscriptions received in the year relating to the following year have not been reflected in the Society's Balance Sheet, and the Society has not complied with the Statement of Standard Accounting Practice No. 10 concerning the Source and Application of Funds. We concur with this treatment of subscriptions and with the departure from the Standard as in our view any other treatment would have resulted in the financial statements giving a misleading view.

In our opinion the Accounts set out on pages 2 to 4† which have been prepared under the historical cost convention, give a true and fair view of the state of affairs of the society at 31st December 1979 and of the surplus for the year ended on that date and comply with the Companies Acts 1948 and 1967.

FRASER THRELFORD & CO.
Chartered Accountants

31 Copthall Avenue,
London, EC2R 7BP

† *Refers to original document*

Balance sheet as at 31st December 1979

1978 £		Notes		£
119,924	*FIXED ASSETS*	2		140,043
8,927	Investment at Cost			12,567
	CURRENT ASSETS			
—	V.A.T. Recoverable		222	
50,782	Bank : Deposit Account		8,021	
102	Cash in Hand		132	
				8,375
179,735				160,985
	LESS: CURRENT LIABILITIES			
—	Accountancy and Audit		200	
—	London Borough of Lambeth: Loan		5,596	
42,861	Bank Overdraft	3	29,911	
3,000	Pension Fund		—	
10,113	Capital Creditor		—	
55,974				35,707
123,761				£125,278
	Represented by:			
	ACCUMULATED FUND			
94,103	Balance at 1.1.1979			123,761
29,658	Excess of Income over Expenditure for year			1,517
£123,761				£125,278

Income and expenditure account for the year ended 31st December 1979

1978 £			£	£
	INCOME			
44,502	Subscriptions from members		47,591	
33,877	Sale of Publications		27,082	
3,906	Income from Investments		3,927	
1,344	Sundry Receipts		681	
83,629				79,281
	Less: Expenses			
	Office and Administration			
8,357	Salaries and National Insurance,		14,273	
2,383	Rent, Rates, Light, Heat, Cleaning, Insurance and Repairs		5,138	
70	Audit & Accountancy			
	1978 Audit	145		
	1979 Audit	160		
	1979 Accountancy	40		
			345	
2,911	Postage, Stationery and Telephone		4,953	
618	Sundry Expenses		403	
—	Depreciation:			
	Buildings		2,814	
—	Fixtures and Fittings		1,448	
	Publications and Meetings			
38,722	Publication of Magazines		47,571	
508	Meeting Expenses		429	
402	I.A.F. Contribution and Expenses		390	
53,971				77,764
£29,658	Excess of Income over Expenditure			£ 1,517

BENEVOLENT FUND

ACCOUNTS FOR THE YEAR ENDED 31.12.1979

Appeal Account	1979	1978
Balance at 1.1.1979	6774	6367
Donations	—	8
Interest and Dividends (Gross)	833	465
	7607	6840
Less Grants	—	66
	7607	6774

Investments	1979	1978
2222 Save and Prosper High Yield Units	773	697
2640 Save and Prosper Group Units	824	744
Bank Deposit	6010	5333
	7607	6774

The market value of the quoted investments at 31.12.79 was £2045.

Notes to and forming part of the accounts
for the year ended 31st December 1979

1. (a) *Depreciation:* Depreciation has been provided at rates which are considered appropriate in reducing the cost of the assets to their residual value over their estimated useful life. The rates used are:

Freehold Building - 2% on a straight line basis
Fixtures and Fittings - 10% on a straight line basis

2. *FIXED ASSETS*

	Freehold Land	*Freehold Buildings*	*Fixtures and Fittings*	*Library*	*Total*
	£	£	£	£	£
COST					
Balance at 1.1.1979	33,963	113,362	5,270	—	152,595
Additions during year	—	27,328	9,214	11,467	48,009
Balance at 31.12.1979	£33,963	£140,690	£14,484	£11,467	£200,604
DEPRECIATION					
Depreciation at 1.1.1979	—	—	2,010	—	2,010
Charge for year	—	2,814	1,448	—	4,262
Balance at 31.12.1979	£ —	£ 2,814	£ 3,458	£ —	£6,272
Balance at 31.12.1979	33,963	137,876	11,026	11,467	194,332
Less: Donations received	—	36,351	6,471	11,467	54,289
N.B.V. 31.12.1979	£33,963	£101,525	£4,555	£ —	£140,043

3. BANK OVERDRAFT

During the latter part of 1979 £39,120 (1978 - £35,663) being subscriptions relating to the following year were received and utilized to clear the bank overdraft. This amount is not reflected in these accounts because your Council are of the opinion that inclusion would show a misleading view of the financial affairs of the society.

REPORT OF THE COUNCIL FOR THE YEAR ENDED 31 DECEMBER 1979

Introduction

1979 saw the putting into practice of the Council's 1978 decision to involve many more members in the organization and administration of the Society by extending and broadening the Committee structure. These Committees have met regularly throughout the year and many important decisions have been taken by them concerning the future activities of the Society. Some of these decisions (such as increasing the number and scope of the Society's meetings) have already been put into practice - others need more working out in detail and will engage the attentions of the committees and Council for some time. Having stated that, I must add of course that the burden of implementing the decisions of all committees and those of Council itself, and of carrying out all the office work associated with this extended committee structure falls upon the Society's permanent and part-time staff.

New BIS Headquarters

The year under review was a momentous one in the history of the Society, for it saw our removal from cramped rented offices to new Headquarters which are eight or nine times as large and our own freehold property. This was the culmination of years of planning and careful financial administration by the Society's staff, officers, Council, and committees, and especially by our Executive Secretary, Mr. Leonard J. Carter. However, we could never have acquired and partly equipped the new premises without the support of members and friends. Some were able to give advice or assistance in the reconstruction of or removal to the South Lambeth Road building; many at home and abroad made contributions to the Appeal Fund which enabled the building and furnishing to go ahead. To all of you, I wish to express the Society's deepest thanks. Whenever you have cause to visit the Society's headquarters - or even just see a photograph of it or hear it mentioned - you can think with pride; "I played my part in providing this building and thus assisted the work of the BIS in promoting astronautics".

Council had originally agreed in 1978 to go ahead with the new offices as an essential first step for the future development of the BIS. The Society's financial reserves at that time were insufficient to complete the project - indeed, as anyone who has ever arranged for building work to be undertaken will understand, it is impossible to be precise about the final sum. Apart from inflation, there are always unexpected snags and "extras". We had faith that members and friends would rally to support the Society in this critical period and our faith proved to be well-founded. Donations for the project poured in, and these continued to be received throughout 1979. Every donation, no matter whether small or large, is greatly appreciated.

The first few months of 1979 saw the final stages of the rebuilding, involving provision for flooring, lighting, decorations, installation of power supplies, heating, and kitchen equipment. This was also a time for selecting and ordering equipment for the library, lecture room, and offices. The Immediate Past President, Professor G. V. Groves, also played a major part in this work. In addition to monitoring the operations in the new building, Mr. Carter had to ensure that

the normal work at the old office continued unchanged, so both he and the other members of staff had to work extended hours during this period.

The move to 27/29 South Lambeth Road took place on 1 May 1979 but workmen continued to appear at intervals well into 1980. Small maintenance defects became apparent and after their rectification the decorations had to be touched up. The basement in the "listed building" (No. 29) was found to be excessively damp, so Council had to authorize its being stripped, sealed, and made waterproof - an expensive undertaking due to be carried out in 1980. Because of the architectural significance of the building as well as the need to protect the rest of the building and its contents, immediate action was essential. Apart from this work, which is in progress at the time of writing, the building operations are substantially complete.

An Appreciating Asset

We now have a freehold property acquired at a net cost of about £190,000. The site alone cost £30,000 but the small piece of waste land adjoining the Society's office was recently offered for sale at about £100,000, indicating that our building is worth substantially more than the book value. The building is in a central and very accessible location. It is only just across the river from our previous headquarters and can be readily reached by bus or train (it is only a few hundred metres from a Victoria Line station) - also by car, once one has mastered the correct methods of negotiating the one-way system. Since the establishment of the National Theatre in 1951 there has been a steady migration of offices and commercial premises to the South Bank; this is gaining in impetus and we have every reason to think that our Headquarters will increase in value, as will the desirability of the neighbourhood.

Although we have a considerable asset, the final account for the building shows that we still have to repay the £30,000 bank loan that was approved at the 1978 AGM. Such is the financial position as regards the building itself, but that does not cover furnishing and equipment. Here Council decided to concentrate on essentials and therefore authorized the purchase and installation of only those items necessary for the staff to carry out their duties adequately and for members to use the open areas of the building - the reception room, the lecture room, and (in due course) the library. The lecture room has been provided with modern projection equipment and serviceable seating - not perhaps as comfortable as Council would wish for members and guests, but adequate for its purpose. The Library is not yet operating, for our financial position has prevented us from providing the additional stock and facilities it badly needs and this has slowed down the work.

Other major items of expenditure which we have had to forego for lack of funds include the provision of a projection booth (to reduce unwanted noise at film shows) and of double glazing. The latter is desirable, not only to reduce noise from the busy road outside and the nearby railway but also to reduce heat loss - important at a time of steeply rising fuel costs.

Publications

This brings me to another financial problem we have to face - that of running expenses. The previous Report of Council had stated that we were contemplating the purchase of two more IBM Composers for use in producing our publications, as the existing machines were approaching the end of their useful life. During the course of the year it became clear: (a) that these machines were no longer going to be marketed and that the new generations of devices which were replacing them (computer-controlled word-processors) were beyond our means, and (b) that our employees could not continue to work under the excessive pressure we had demanded of them in the past (nor were we in a position to improve or even maintain the staffing level, for suitably qualified personnel were not available). With these considerations before Council, there was no option but to return to our previous method of producing our publications, namely, wholly by commercial printers.

1979 CALENDAR OF EVENTS

GENERAL MEETINGS AND LECTURES

17 Jan	Science Museum, second visit.
1 Feb	Short Paper Evening: (a) "Exotic Semi-Conductor Materials" by A. T. Lawton (b) "Interstellar Colonization" by L. J. Cox
14 Feb	Visit to PERME, Westcott.
2 March	Western Branch Film Show at University of Bristol
8 March	Space Miscellany: (a) "Space Paintings" by D. Earley (b) "Space Reporter" by R. Turnill
4 April	Lecture: "Astronomy from Orbit" by W. I. McLaughlin.
9 May	Space Miscellany: (a) "Satellite Tracking" by M. Sweating (b) "Space Photographs" by J. I. Stone
16 July	Presentation of BIS Bronze Medal to Captain R. F. Freitag at US Embassy, London.
28 Aug	An Evening with Arthur C. Clarke.
9 Oct	Lecture: "Beyond Saturn" by C. E. Hunt.
21 Nov	Lecture: "The International Solar Polar Mission" by D. Eaton.
4 Dec	Return visit to PERME, Westcott.

TECHNICAL SYMPOSIA AND CONFERENCES

3-5 July	16th European Space Symposium. Stresa, Italy: *Theme:* "Current and Potential European Space Projects".
2-6 July	8th IFAC International Symposium, co-sponsored by BIS: *Theme:* "Automatic Control in Space".
11-12 Sep	3rd BIS Conference on "Interstellar Studies".
17-22 Sep	30th IAF Congress: "Space Developments for the Future of Mankind" - Munich, Germany.
15-16 Nov	3rd Computers and Space Technology Conference: *Theme:* "Image Processing Techniques Applied to Astronomy and Space Research" - SRC Appleton Laboratory, Slough.

STUDY COURSE *Theme:* "The Origin and Evolution of the Universe".

3 Oct	"The Primordial Fireball" by I. Robson.
2 Nov	"Quasars and Seyfert Galaxies" by R. F. Creswell.
5 Dec	"The Extragalactic Distance Scale" by D. A. Hayes.

BUSINESS MEETING

13 Sep	34th Annual General Meeting.

OTHER EVENTS

27 April	Removal of BIS Headquarters from 12 Bessborough Gardens to 27/29 South Lambeth Road, London SW8 1SZ (Tel: 01-735 3160).
19 Oct	BIS Anniversary Supper, Surrey Hall, London SW8 and tour of new BIS Headquarters.

Delivery of publications has presented yet more problems through 1979 and these will probably remain with us throughout the foreseeable future. I refer to delays in delivery caused by the Post Office about which we are powerless to do anything. We are sorry when they occur and do our best to rectify matters but it is not in our power to eliminate them. We apologize, especially to our overseas members and readers, who sometimes experience excessive delays since the transmission of journals involves at least two postal authorities and a shipping or airline company, so probability theory suggests the possibility of a strike or go-slow interrupting the chain of communications is from four to nine times as great as at home.

I shall not dwell in detail upon Membership, Meetings and Publications. I will only comment that it is good to see that our membership totals are still resilient but we still need to aim for a much larger membership and to ensure that such members make an adequate contribution to the finances of the Society.

Since the new Headquarters building came into operation good use has been made of the Meetings rooms and other facilities. The popularity of our meetings has given satisfaction

MEMBERSHIP OF THE BIS COUNCIL
President: C. V. E. Thompson

Vice Presidents: A. T. Lawton
C. R. Turner

Other Members: Dr. E. J. Becklake, Dr. W. F. Hilton, P. J. Conchie, Dr. W. F. Maxwell, K. W. Gatland, Dr. L. R. Shepherd, Prof. G. V. Groves, G. J. N. Smith, G. E. Webb

to the Council; and it was also good to see that our first Social event for some years proved such a success. The larger part of our members are unfortunately unable to attend most London events and we hope that our publications have interested and will continue to interest them. This interest must not be a passive process though – Council and its committees need feedback on all aspects of the Society's work and indeed all aspects of astronautics. If you are technically inclined or an expert in this field, papers will be welcome and will be considered for publication, but even if you are not, letters and comments are appreciated.

The accounts are attached and I hope that you will regard them as satisfactory. We have the great asset of our new Headquarters and in these times of soaring inflation this represents a much better investment than money in the bank. It also represents a great asset in respect to furthering the work of the Society. Nevertheless, we still need to have an adequate income to meet the rising operating costs. (Local rates have just been increased by 50%). These charges will be partly met by the stringent economies the Council has already authorized and by a stricter watch upon our finances by the Executive Committee and Mr. Carter. Inevitably we must now contemplate increases in subscriptions to make good the ravages due to inflation, although the Council will endeavour to keep these as low as possible.

We trust that you will recognize the value of the work the Society is doing and will support the conduct of the Society by Council and its Committees throughout the coming year. You can show your approval by renewing your membership and/or subscriptions, attending our meetings when possible, and submitting papers or correspondence for possible publication. You can also assist our finances in many ways – by purchasing special publications (such as *High Road to the Moon*), etc., by responding to our appeal for donations, by making a bequest in your will, or, at no cost to yourself, by completing a Deed of Covenant. 1979 was a year of solid construction for the Society. 1980-81 look like being rather lean years financially, though Council, Committees, and Staff will be working hard to see the BIS through this period to the years of promise that lie ahead. I hope that every member will rally to the Society to see that we reach our fiftieth anniversary in 1983 in good shape.

Let that be the task before us in the coming year.

Gordon V. E. Thompson,
President

POSTAGE COSTS
In view of the recent heavy increase in the cost of postage we are asking all members communicating with the Society and its officials to enclose a stamped addressed envelope for reply.

FOR SALE. Due to shelf clearance, I have a number of press kits, slides and booklets for sale. Please send S.A.E. for list to: Nicholas E. Steggall, 213 Ealand Rd., Batley, WF17 8JL, West Yorkshire.

MEMBERSHIP DUES

Inflation in the UK halves the value of money and so doubles the costs of our publications and running costs every four years. On this basis fees ought to have doubled during the same period, if only to maintain their purchasing power to meet the higher postage, publications and other costs.

Our fees, however, have done no such thing. The result is that, although members have paid the same sum each year, the value, i.e. what we can buy with it, has been lowered each time with the result that in reality, members have been progressively paying less and less each year. Up to now we have been able to keep our organisation, facilities and publications afloat, mainly through the efforts of a dedicated staff and a programme of rigorous economies which have become more and more severe each year.

The position has been made even more acute by the fact that we spend so much on publications and inflation, in the printing world, has been at a rate above the National level.

We have, at last, reached the position when no more economies are open to us. Our staffing level is dangerously low and there is no alternative other than to bring the membership fees in line with the real costs of what we do and publish.

Many members will recall, no doubt, that in many cases the margin of their fees left over to pay for our offices, staff, administration and many other functions is Nil. Only Senior Members, Associate Fellows and Fellows contribute: Student Members are subsidised and Members pay just enough to cover the publications they receive.

When one reflects that about £3 per member is now absorbed simply on the postage and despatch of one magazine per year, to which must be added the cost of administering membership records, addresses and subscriptions, one can see that not a lot is left. If one considers overheads, then general rates alone (payable to the local authority) work out at £1 per member, without allowing for electricity, gas, telephone, postage, stationery, etc. nor the payment to the IAF for each member, and these are just a few examples from many.

Many of our plans depend on attracting new members, but this cannot be accomplished in the short term. We have been very successful in increasing our income in leaps and bounds in non-membership areas, e.g. Library sales, but this is insufficient to cover what is, basically, the simple fact that membership dues have not kept pace with inflation: the plain truth is that the money we receive from members has only 50 per cent of the value of what it was 5 years ago, so it simply isn't enough to go round.

Had the Society increased its fees annually to keep pace with inflation, as many other bodies have done, we would be the richer now, but the Council's intention is and always has been to keep subscriptions at the lowest possible level.

For 1981, however, some adjustment is necessary. Indeed, it is forced upon us. We have to make up some of the ground for previous years. This is why we must increase our subscriptions if our publications and services are not to suffer considerably.

In real terms the rate last year should have been about £20; this year, with inflation at 20 per cent it should be £24. In fact, members paid only £12 last year, and that after 4 years without any increase at all. If they are asked to pay 50 per cent more this year, i.e. £18 this is still far below the going rate but is the minimum necessary if we are to keep up our present level of activity.

Extracted from a Report by the Secretary to the BIS Council.

BOOK REVIEWS

PUBLICATIONS RECEIVED

Communication with Extraterrestrial Intelligence
Eds. J. Billingham and R. Pesek, 232, Pergamon Press, 1979, £17.50

These papers deal with concepts and studies related to the science, technology and observational techniques of communications with extraterrestrial intelligence.

CONTENTS (Partial): On the strategy of searching for extraterrestrial civilizations, N. S. Kardashev. Recent concepts of the problems of the origin of life, L. M. Mukhin. An extended Drake's equation, the longevity-separation relation, equilibrium, inhomogeneities and chain formation, R. N. Bracewell. Search for radio emission from extraterrestrial civilizations, V. S. Triotskii *et al.* Rationale for the water hole, B. M. Oliver. An infinitely expandable space radio-telescope, V. I. Buyakas *et al.*

Origin of the Earth and Moon
A. E. Ringwood, 295, Springer-Verlag, 1979, $24.80

The book has three main divisions. Part 1 deals with the composition and constitution of the Earth, i.e. the Mantle-Crust System, geochemistry of the Mantle, composition and formation of the Earth's core and boundary conditions for the origin of the Earth. Part 2 examines the Earth's origin in more detail, beginning with Protostars, Disks and Planets and dealing with the formation of Planets in the primordial solar nebula. Early theories of accretion and homogeneous accretion are examined. Part 3 concerns the Moon and Planets. It discusses the terrestrial planets, asteroids and meteorites and then examines the constitution and composition of the Moon, together with its geochemistry, ending with a view of theories of the Lunar origin.

La lutte pour l'Espace (in French)
Alain Dupas, 288, Seuil, Paris, 1977

Published to coincide with the twentieth anniversary of the space age, the book is an historical account of the first twenty years compiled by an author with a particular interest in the Soviet space programme. The first part, ending with the landing of Apollo 11 on the Moon is sub-titled "The Cold War in Space". The second part deals with developments since that time including the detente which led to the Apollo-Soyuz flight in 1975 and the military escalation on the other hand of the hunter-killer flights, commercial applications, future space transportation systems, etc. The author attempts analyses of relationships between the Earth and the Moon, between politicians and astronauts, and the impact of the space programme on contemporary history, but not in great depth.

Student Success
Sir, May I take this opportunity to thank the Society for its grant of £50 which enabled me to travel to the IAF Congress in Munich. As you may know my paper has been selected by the IAF for inclusion in the issue of *Acta Astronautica* dedicated to the Congress, so I cannot submit it for inclusion in *JBIS*. However I hope to have in the near future a related article which I will submit to *Spaceflight* in the hope of publication.

BRIAN DERBY,
Wolfson College,
Cambridge.

In our original report of Mr. Brian Derby's success (*Spaceflight*, June 1980 p. 263) a slip of the editorial typewriter caused his name to be rendered as Brian Day, for which we apologise. We look forward to receiving Mr. Derby's promised follow-up article. Ed.

HIGH ROAD TO THE MOON, paintings by R. A. Smith & text by Bob Parkinson, British Interplanetary Society, 1979, pp. 120, £6.00

Until Sputnik 1 expanded our horizons in 1957, the concept of space travel in the near future was widely scorned by the public. Yet societies like our own contained a hardcore of people who *knew* that such a thing was possible and would become reality sooner rather than later.

Ralph Smith was at the very heart of BIS activities and he played a significant part in producing the Moonship study of 40 years ago. His lasting contribution, though, was not in technical matters but in the way his paintings and drawings depicted Man conquering near-Earth space and eventually making his way to the Moon and other planets.

He was one of that rare breed of illustrators who thoroughly knew the subject and could produce pictures reflecting the state of knowledge at that time. He was certainly not a great artist, but the combination of his competent artistic skill and technical knowledge made him one of the most important illustrators of early astronautics.

The Society bought 140 of his paintings, mostly produced between 1945 and 1955, and through *High Road to the Moon* they will now reach a much younger, wider audience. The title page of the book is rather misleading because it gives the impression of a detailed study of Smith's work but the text works at a more popular level than that.

Bob Parkinson has tailored his writing to fit three guidelines:

(1) what was the state-of-the-art at a particular period?

(2) how did Smith represent this in his paintings? and

(3) how did it *really* happen in the space race?

For example, the BIS Moonship of 1939 is discussed at some length without glossing over its limitations. With hindsight, using solid propellant motors for landing men on the Moon seems inexcusable, but that would be to miss the point: the designers were using the best information of that time and Smith incorporated their ideas into his paintings. For the same reason, his spaceships and spacesuited astronauts look very antiquated though, even to the untrained eye, they have potential. Perhaps a better way of looking at what the pictures were really about, rather than being distracted by our knowledge of what actually happened, is to study scenes depicting events which we have yet to witness. In that light, the painting of a probe approaching a comet takes away some of our prejudices.

Probably one of the most interesting series of pictures illustrates the colonisation of the Moon, beginning with the first landers and taking us through the establishment of mines and hydroponic farms. Smith obviously considered that lunar colonies would quickly follow the first landings but even he failed to foresee the political nature of the real Moon landings. His paintings will spring to life when we go back to the Moon for good, hopefully before the end of the century.

High Road to the Moon is the book that needed writing to bring Smith's pioneering work to our modern attention and it may be that reproductions of his work will now start appearing more often in texts on astronautics history.

Smith died in 1959 after seeing Sputnik and Explorer take to the skies. It is indeed unfortunate that he did not survive to produce paintings for Project Daedalus — interstellar travel would have appealed to him enormously.

ANDREW WILSON

SATELLITE DIGEST–139

A monthly listing of all known artificial satellites and spacecraft. A detailed description of the information presented can be found in the January 1979 issue, p. 41.

Compiled by Robert D. Christy

Continued from June issue

Name, designation and object number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch site launch vehicle and payload/launch origin
Cosmos 1155 1980-9A 11685	1980 Feb 7.46 14 days (R) 1980 Feb 21.3	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	194 360	395 412	72.87 72.86	90.45 92.31	Plesetsk A-2 USSR/USSR (1)
Big Bird 1980-10A 11687	1980 Feb 7.88	Cylinder? 13300 fuelled?	15 long? 3 dia?	224	502	96.97	91.87	WTR Titan 3D DoD/USAF (2)
Navstar 5 1980-11A 11690	1980 Feb 9.96 indefinite	Cylinder+4 vanes 433?		162 20083	20136 20146	63.08 63.72	352.42 715.24	WTR Atlas F DoD/USAF (3)
Cosmos 1156-1163 1980-12A-H 11691-11698	1980 Feb 11.98 10 000 years	Spheroids? 40?	1.0, long? 0.8 dia?	1400 1417 1436 1451 1467 1469 1471 1471	1474 1477 1476 1479 1483 1503 1522 1545	74.04 74.02 74.02 74.01 74.01 74.02 74.02 74.02	114.64 114.86 115.06 115.27 115.48 115.72 115.95 116.21	Plesetsk C-1 USSR/USSR (4)
Cosmos 1164 1980-13A 11700	1980 Feb 12.04 12 years?	Cylinder-cone+6 panels+antennae? 1250?	4.2 long? 1.6 dia?	435	40858	62.82	736.86	Plesetsk A-2-e USSR/USSR (5)
SMM 1980-14A 11703	1980 Feb 14/665 10 years	Cylindrical box +2 panels 2315	4.0 long 2.3 dia	563	570	28.51	95.80	ETR Delta NASA/NASA (6)
Tansei 4 1980-15A 11706	1980 Feb 17.028 10 years			518	604	38.68	95.75	Kagoshima Mu 3S Japan/Japan (7)
Raduga 6 1980-16A 11708	1980 Feb 20.34 indefinite	Cylinder+2 panels +2 antennae?	5 long? 2 dia?	36535 35734	36720 35844	0.55 0.41	1479.2 1436.1	Tyuratam D-1-E USSR/USSR (8)
Cosmos 1165 1980-17A 11713	1980 Feb 21.50 13 days (R) 1980 Mar 5	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	170 156 155	353 330 350	72.88 72.87 72.85	89.78 89.51 89.59	Plesetsk A-2 USSR/USSR (9)
ECS 2 (Ayame) 1980-18A 11718	1980 Feb 22.35 indefinite	Cylinder 260	1.5 long 1 dia	213	35592	24.53	627.04	Tanegashima Nu Japan/Japan (10)
1980-19A 11720	1980 Mar 3.47 2000 years			1060	1147	63.50	107.34	WTR Atlas F DoD/USAF
Cosmos 1166 1980-20A 11722	1980 Mar 4.44	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	197 356	380 430	72.85 72.86	90.32 92.46	Plesetsk A-2 USSR/USSR (11)

Supplementary notes:

(1) Orbital data are at 1980 Feb 7.5 and Feb 8.3.
(2) Manoeuvrable reconnaisance satellite.
(3) US navigation satellite. Orbital data are at 1980 Feb 10.4 and Feb 13.6.
(4) Multiple launch of eight satellites, possibly for military communications. One orbit is shown for each satellite.
(5) Possibly a failed Molniya-1 satellite.
(6) Solar Maximum Mission, launched by NASA to observe the Sun during the 1980-81 maximum of the sunspot cycle. SMM will measure gamma ray, x-ray and ultraviolet emissions, as well as observing the corona and measuring the solar constant. The satellite may possibly be retrieved from orbit during a Shuttle mission.
(7) Japanese built and launched scientific satellite.
(8) USSR communications satellite in geostationary orbit, located above 35 degrees east longitude, the Statsionar 2 position. Orbital data are at 1980 Feb 22.4 and Mar 10.4.
(9) Orbital data are at 1980 Feb 21.9, Feb 28.3 and Mar 2.1.
(10) Japanese Experimental Communications Satellite. Contact was lost at the time the apogee motor should have fired. ECS 1 (1979-9A) was lost when it collided with the third stage of the launcher.
(11) Orbital data are at 1980 Mar 4.7 and Mar 5.0.

Amendments:

Add the following object numbers:

Designation	number
1979-6A	11255
1979-7A	11256
1979-8A	11259
1979-9A	11261
1979-15A	11273
1979-17A	11278
1979-35A	11343
1979-38A	11353
1979-69A	11465
1979-70A	11474
1979-71A	11478
1979-72A	11484
1979-73A	11485
1979-76A	11496
1979-78A	11510
1979-83A	11536
1979-84A-H	11538–11545
1979-85A	11548
1979-86A	11558
1979-87A	11561
1979-89A	11573
1979-90A	11585
1979-104A	11645

The following launches were from the WTR, not the ETR as listed:

1973-101A; 1975-17A; 1976-38A; 1979-53A; 1978-20A; 1978-75A; 1978-93A, and 1978-112A.

1974-54A, add the launch vehicle which is an Atlas.

1974-55A, add the launch vehicle which is a Scout.

1975-100A and 1977-48A are named GOES 1 and GOES 2 respectively.

SOLAR POWER FOR RURAL USE

The Jet Propulsion Laboratory, has awarded a contract to the General Electric Company's Space Division to design and build prototype units with which solar energy may provide electrical power to small communities and rural areas in the future.

The 16-month $1.2 million contract was awarded by Jet Propulsion Laboratory for the US Department of Energy. It is the second part of a two-phase Energy Department programme to develop a low-cost, point-focusing solar concentrator.

Under the contract, General Electric will build three dish-shaped solar thermal energy concentrators to generate electrical power which will be installed at JPL's Solar Thermal Test Site at Edwards, California.

Each concentrator will be 12 metres (40 ft) in diameter and will include the mechanism that allows the concentrator to track the Sun. A point-focusing solar concentrator directs mirror-reflected solar radiation to a centrally located heat absorber connected to a heat-driven engine and generator. Heat absorbers and heat engine generators for the installation are being developed under separate contracts.

The goal is to obtain the greatest thermal performance at the least cost.

Soviet Space Activities

Sir, I must take strong exception to T. R. King's letter in the January *Spaceflight*. It is true that you give extensive coverage to Soviet space activities, but you also give extensive coverage to US and other "Free World" space activities. *Spaceflight* is the only magazine giving this information to which many (myself included) have access.

Perhaps you will give more coverage to US space activities when there is something to cover.

JOHN FADUM,
Deerfield Beach,
Florida, USA.

Spacecraft Attitude Determination and Control

Ed. James R. Wertz, D. Reidel Publishing Company, 1978, xvii + 858 pp., $47.00.

The preparation of this book was a cooperative effort involving the contributions of 35 members of the technical staff of the Attitude Systems Operation of the System Sciences Division of Computer Sciences Corporation under contract to the Attitude Determination and Control Section of NASA Goddard Space Flight Center. The purpose of this endeavour was to provide a comprehensive review of all phases of the attitude support activities including attitude determination, attitude prediction, and attitude control.

It is assumed that the reader will have a background in engineering and physics and familiarity with the elementary aspects of Newtonian mechanics, vector algebra, and calculus. Standard notation is introduced in the early chapters and an attempt to use this is made throughout the text. Unfortunately, notation and the definition of attitude and orientation of the roll, pitch, and yaw axes appear to be employed differently depending on the spacecraft system being described – an inevitable problem of a publication involving multi-authors. The book reflects, to a large extent, the experience of Computer Sciences Corporation in attitude determination and control, and, as a result, the examples concentrate mainly on unmanned, Earth-oribiting spacecraft systems.

A great deal of the material discussed has not appeared in the open literature previously, especially the sections related to attitude hardware and data acquisition (Part II), and attitude determination (Part III). As a result, many of the numerous references cited are to company and government reports and internal documents. A further strength of the text is the liberal usage of figures and tables throughout, especially the usage of the global geometry plots which are convenient for portraying results involving geometrical analysis on the body-centered celestial spheres.

As stated in the foreword portion of the text, this book can serve as a reference for scientists and engineers involved in mission planning, attitude determination, and attitude dynamics, and also as a source of information for experimentors who need a brief explanation as to how spacecraft are controlled and how their orientation are determined. However, whether all parts of the text are also appropriate as an introductory textbook for students and professionals starting in the field is open to question. Although the book contains an abundance of formulae and data, it does not contain sample completed problems or suggested homework problems found in most introductory technical textbooks. A number of such elementary textbooks concentrating on the orbital mechanics part of mission analysis have been cited by the present authors, and several other texts describe the mathematical formulation of attitude dynamics, some with an emphasis on spacecraft applications. However, in the area of attitude determination and attitude data acquisition (to this reviewer's knowledge) no such introductory textbook for beginners is currently available.

PROF. PETER M. BAINUM

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 27/29 South Lambeth Road, London SW8 1SZ

Correspondence and manuscripts intended for publication should be addressed to the Editor, 27/29 South Lambeth Road, London SW8 1SZ.

Opinions in signed articles are those of contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

MEETINGS DIARY

Lecture

Title: **THE DISCOVERY, CARE AND FEEDING OF INTELLIGENT ALIENS**

by Dr. P. M. Morton

To be held in the Golovine Room 27/29 South Lambeth Road, London, SW8 1SZ on **23 July 1980**, 7-9 p.m.

The topics covered will include the physical appearance of aliens in relation to their evolution and environment, how they are likely to have evolved into intelligent creatures, with or without space travel, and the so-called "Fermi paradox". What would be the alien's view of the human race?

Admission will be by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply paid envelope.

Visit

SRC APPLETON LABORATORY

Arrangements have been made for a small party of members to visit the SRC Appleton Laboratory at Ditton Park, Slough, together with a visit to their out-station, the Satellite Signal Reception Centre at Winkfield, on **10 September 1980** (all day).

Registration is necessary. Members interested in receiving further information must apply to the Executive Secretary, enclosing a reply-paid envelope, in good time.

35th ANNUAL GENERAL MEETING

The 35th Annual General Meeting of the Society will be held in the Tudor Room, Caxton Hall, Caxton Street, London S.W.1 on **18 September 1980**, 7.00 p.m.

A detailed Agenda appears in this issue of *Spaceflight*

31st IAF CONGRESS

The 31st Congress of the International Astronautical Federation will be held in the Takanawa Prince Hotel, Takanawa, Minato-ku, Tokyo, Japan from **21–28 September 1980.**

Film Show

Theme: **HISTORY OF ASTRONAUTICS**

A number of early films on astronautics not now generally available will be screened at a meeting to be held in the Golovine Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on 5 November 7-10 p.m.

The programme will include the following:

(a)–History of Rocket Development

(b)–Black Knight

Admission will be by ticket only. Members should apply in good time, enclosing a reply-paid envelope.

Lecture

Title: **SPACE REVIEW – 1980**

by P. S. Clark

A review of space activities throughout the world which have taken place during the past twelve months, to be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ, on **8 October 1980**, 7-9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Visit

Institute of Astronomy

Arrangements have been made for a small party of members to visit the Institute of Astronomy at Cambridge where a tour will be made, conducted by Dr. A.C. Fabian and Mr. A.J. Whyte, on Tuesday, **18 November 1980.**

During the afternoon a trip will be undertaken to see the Radio Telescope at North Barton if sufficient personal transport by members is available. Admission, restricted to members only, will be by registration only. Applications should be sent to the Executive Secretary, enclosing a reply-paid envelope.

Study Course

Theme: **ROCKET TECHNOLOGY**

A course of seven evening meetings will take place on the above topic during the 1980/81 session. Details ars as follows:

3 September 1980	The Early History of the Rocket by Dr. W. R. Maxwell
30 September 1980	The Chemistry of Rocket Propulsion by Dr. J. R. Lyons
22 October 1980	Designing Solid Propellant Rockets by Dr. P. D. Penny
12 November 1980	Evolution and Performance of the Liquid Propellant Rocket by M. R. Fry
10 December 1980	Evening of Technical films on Rocket Development
14 January 1981	Electric Propulsion by D. G. Fearn
11 February 1981	Advanced Propulsion – What Future for the Rocket? by Dr. R. C. Parkinson

The Venue will be the Golovine Conference Room at the Society's Headquarters 27/29 South Lambeth Road, London, SW8 1SZ, 7.00 p.m. Course fee £5.00.

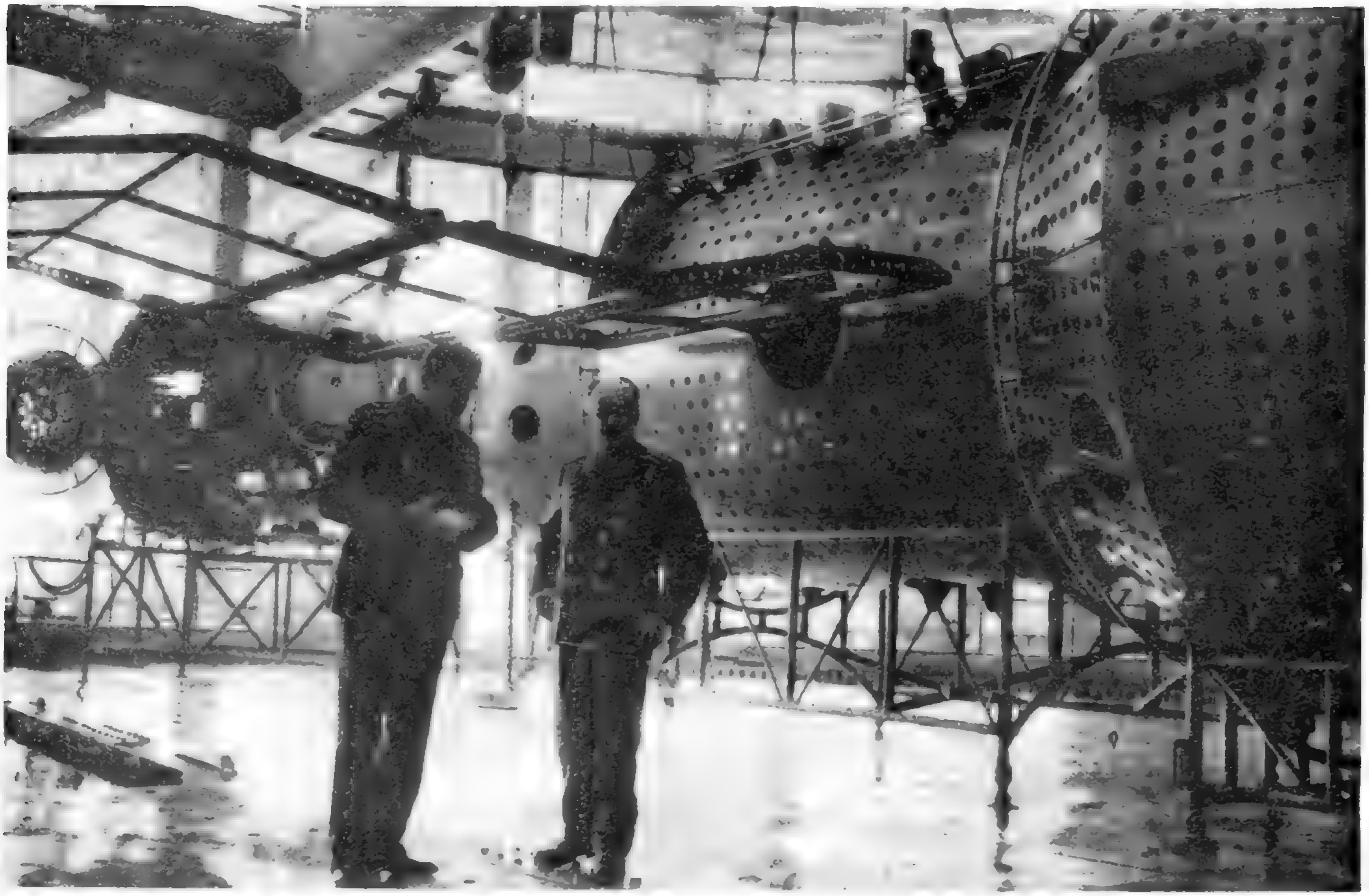
Application forms for registration are available from the Executive Secretary. Please send s.a.e.

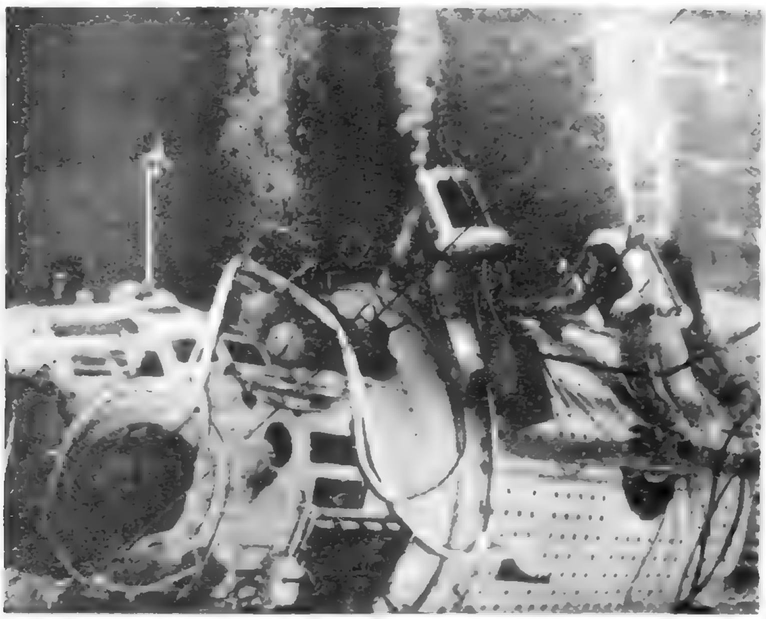
Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published for The British Interplanetary Society Ltd., (No. 402498) by Space Educational Aids Ltd., (No. 741211). Registered Office, 27/29 South Lambeth Road, London, SW8 1SZ, England.

ISSN 0038-6340

SPACEFLIGHT

88905 Космические полеты № Т-9-10
(спейсфлайт)
По подписке 1980 г.





VOLUME 22 NOS 9–10
SEPTEMBER–OCTOBER 1980

Published by
The British Interplanetary Society

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 NOS 9–10 SEPT–OCT. 1980 *Published 15th August 1980*

Editor
Kenneth W. Gatland, FRAS, FBIS

CONTENTS

INFLATION has reduced the value of members subscriptions to the extent that these are no longer adequate to cover the cost of our full range of publications. We are trying to achieve the greatest possible value for money but members will know that the need to increase our income to cover rising costs is now acute and forcing the Society to undertake the most stringent economy measures. We are asking all members to continue their support for our Development Fund Appeal during this difficult period to enable us to maintain our publishing programme. The present issue of *Spaceflight* covers the months of September–October. The next issue will appear in the third week of October.

MILESTONES

April 1980

9 Soviets launch Soyuz 35 from Baikonur cosmodrome with cosmonauts Lt. Col. Leonid Popov and Valery Ryumin. (Spacecraft docked with Salyut 6, forward airlock, 10 April and crew transferred supplies from Progress 8 which had docked automatically 30 March 1980. The cargo craft, undocked on 25 April, reentered the atmosphere over the Pacific the following day). *Items omitted from July-August issue.*

27 Unmanned cargo craft Progress 9 is launched from Baikonur at 0924 hr Moscow time; docks with Salyut 6 aft airlock 29 April; undocks 20 May.

May 1980

18 China launches ICBM test vehicle CSS-X4 between Shuang-Cheng-Tzu and a target area in the South Pacific. A second launch on 21 May ended announced test series.

23 Second Ariane space rocket (02) launched from Kourou, French Guiana, crashes into the sea following first stage engine fault (see page 321).

26 Soviets launch Soyuz 36 from Baikonur at 2121 hr Moscow time with cosmonauts Valery Kubasov, 45, and Air Force Captain Bertalan Farkas, 30 (Hungarian). Docked with Salyut 6 on 28 May for series of experiments with resident crew.

31 Twenty-fifth anniversary of the start of construction of Baikonur cosmodrome in Kazakhstan.

June 1980

3 Re-entry module of Soyuz 35 soft-lands with cosmonauts Kubasov and Farkas some 87 miles (140 km) SE of Dzhezkazgan.

5 Soviets launch Soyuz T-2 spacecraft from Baikonur at 1719 hr Moscow time with cosmonauts Yuri Malyshev, 38, and Vladimir Aksyonov, 45. Craft has solar arrays; also computer-controlled docking system making cosmonauts independent of ground control.

6 Soyuz T-2 docks with Salyut 6/Soyuz 36 complex on aft airlock under manual control after docking system had brought it within 590 ft (180 m) of station. (Soyuz 36 had been re-docked earlier on Salyut's forward airlock). Cosmonauts tested "various mechanisms and new on-board systems; before starting a manoeuvre the computer asks the crew's permission and only with this does it proceed . . . electronic devices can now change the orbit and orient the ship to any given star speedily and with lower fuel consumption." During the flight new spacesuits were tested; a "refraction" experiment involved observing and photographing the rising and setting Sun over the Earth's horizon. Visual observations and photography of Earth and oceans involved use of the station's spectrophotometer and multi-band cameras.

Continued overleaf

COVER

HYDROLAB. At the Yuri Gagarin Cosmonauts' Training Centre outside of Moscow, engineers have recently installed mockups of the Salyut space station and Soyuz ferry in a huge water tank which is the central feature of the Centre's new Hydro-Laboratory. *Top*, Lt-Gen. Georgi Beregovoi, director of the Training Centre (left) and Hero of the Soviet Union Nikolai Kamanin inspect the tank during preparations. *Bottom*, the tank now filled with water gives cosmonauts a "feel" for spacewalking on the outside of the Salyut station. The men have been able to simulate repair and maintenance tasks under conditions which are as close to weightlessness as it is possible to achieve in a ground laboratory. The Hydro-Lab is being used in the training of the growing band of international cosmonauts at the Centre.

Novosti Press Agency

6 NASA announces that two of three Space Shuttle Main Engines that will power "Columbia" on its maiden flight have demonstrated their flight readiness in test firings at NASA's National Space Technology Laboratories near Bay St. Louis, Mississippi. Engine 2005 was test fired for 520 seconds on 2 June; engine 2006 for a similar period on 5 June.

9 Re-entry module of Soyuz T-2 soft lands some 124 miles (200 km) SE of Dzhezkazgan.

FROM THE EXECUTIVE SECRETARY. Recent Wage Awards over which we have no control are adding £10,000 per annum to the cost of producing our magazines i.e. £3 per member on this single item alone, and excluding the paper rise which added a further £1 per member earlier this year. The burden we have to bear is overwhelming, for this excludes the incidental rises in printing costs and ignores completely anything to do with the Society's overheads such as rates, electricity, gas, telephone, postage, stationery, etc – and totally excludes staff salaries. Are we now the only body where our staff is progressively paid less and less, though the post box is thick with requests from members and others for more and more services?

PHOBOS AND DEIMOS:

By Geoffrey Bowman

THE MARTIAN ASTEROIDS

Introduction

On 15 October, 1977, as a result of one of the most remarkable examples of deep-space navigation, the American Viking 2 spacecraft was manoeuvred within 26 km (16 miles) of Deimos, the smaller and more distant of the two moons of Mars. This is the closest flyby encounter of any celestial body yet achieved and, in the centenary year of the discovery of the moons, was a fitting culmination of a detailed survey carried out by the two Viking spacecraft and their predecessor, Mariner 9.

Although only discovered in 1877, the existence of Phobos and Deimos had been predicted almost three centuries earlier by the astronomer Johannes Kepler. A great lover of mathematical progressions, Kepler reasoned that, since the Earth had one moon, and Jupiter was known (at that time) to have four, Mars should have two.

Kepler's reasoning does not appear to have gone unnoticed. In 1726, "Gulliver's Travels", by Jonathan Swift, was published. During one of his lesser-known journeys, Swift's hero visits the airborne island of Laputa, and describes how the Laputan astronomers "... have likewise discovered two lesser stars, or 'satellites', which revolve around about Mars, whereof the innermost is distant from the centre of the primary planet exactly three of its diameters, and the outermost five; the former revolves in the space of ten hours and the latter in twenty-one and a half ..." Swift's guesswork is all the more remarkable in that it accurately predicts one of the unique features of Phobos, namely that it orbits Mars more rapidly than the planet rotates [1].

In "Micromégas", a story by the French writer Voltaire, published in 1752, Mars is also credited with two moons. Kepler's explanation was that, since Mars is further from the Sun than the Earth, two moons would be required to provide sufficient light! [2].

It should be noted that, by the 18th century, astronomers were aware of moons orbiting planets more distant than Mars, so it was a reasonable assumption that Martian moons, if they existed, had to be comparatively small and difficult to detect. William Herschel failed to discover any in 1783, using a 48-inch reflector. Further attempts during the Mars oppositions of 1862 and 1864 by Heinrich d'Arrest at Copenhagen Observatory were equally fruitless.

Then, in August 1877, Asaph Hall, an astronomer at the US Naval Observatory in Washington DC, began a series of searches using a 26-inch refractor which at the time was one of the world's finest telescopes. After initial failure, but helped by the encouragement of his wife, Hall made a sighting in the early morning of 11 August. On 17 August he discovered a second faint moon, even closer to Mars. He named the inner satellite "Phobos" (fear) and the outer one "Deimos" (terror) after the horses which pulled the chariot of the God of War in Greek mythology [3].

Observations from Earth

Telescopic observation of Phobos and Deimos is not easy as they are never displaced more than 22 and 56 arc seconds, respectively, from the centre of the Martian disc. Atmospheric distortion and the rapid movement of the moons adds to the difficulty of making accurate measurements, although the use of various filters and Mars-occulting devices can greatly reduce the problem of Martian glare.

The first photometric observations of the moons were made between 1877 and 1882 by Oliver Wendell and Edward Pickering at the Harvard College Observatory. Their measurements, though crude, suggested that Phobos was the brighter of the two and that both were greyish in colour, as distinct from the red colour of Mars. During the very favourable 1956 opposition, Gerald Kuiper (working at McDonald University, Texas) found Phobos to have an approximate mean visual magnitude of +11.6, while the figure for Deimos was approximately +12.8 [4]. Assuming both moons had roughly the same albedo as Earth's moon, he calculated their diameters to be approximately twelve kilometres and six kilometres, respectively, thus confirming Phobos and Deimos as the smallest known natural satellites in the Solar System.

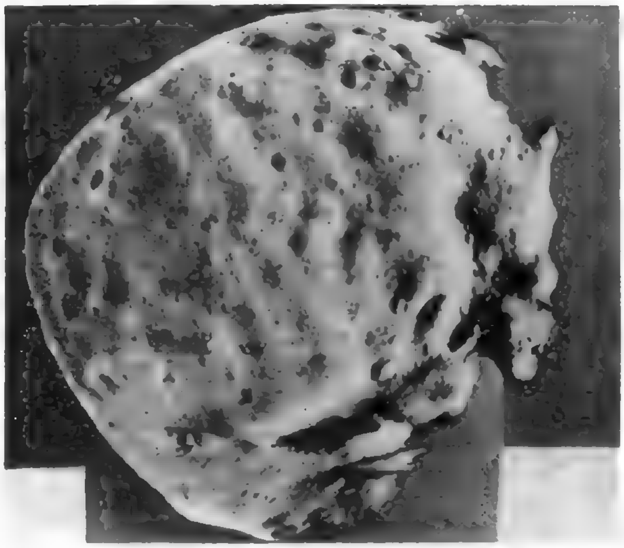


Fig. 1. PHOBOS, inner moon of Mars, as seen from Viking 1 on 18 February 1977, from 300 miles (480 km). Visible features include surface grooves, numerous craters and a prominent linear ridge (right).

NASA

During the 1967 opposition, D. Pascu of the US Naval Observatory found the magnitude of both satellites to be about 0.4 magnitudes brighter than Kuiper's estimates.

Orbital Characteristics

Both Phobos and Deimos lie in almost circular orbits with little inclination to the Martian equator (about 1.1 and 1.8 degrees, respectively). Both are relatively close to Mars, Phobos orbits only 5,920 km above the Martian surface, which is 2.7 radii or 9,400 km from the centre of the planet. This is barely outside the Roche limit of Mars which, at about 8,700 km from the centre of the planet, is the critical distance inside which tidal disruption would pull apart any non-solid body, or prevent loose material from accreting into a single cohesive body. Deimos is more remote, being 6.9 radii from the centre of Mars (23,500 km) or 20,120 km above the surface. This is not very far beyond the synchronous orbital position.

Phobos orbits Mars in only 7 hours 39 minutes. Since the Martian day is an Earthlike 24 hours 37 minutes, Phobos is one of only two moons in the Solar System known to orbit faster than its primary rotates. (The other is a "new" moon of Jupiter discovered by Voyager 2). By comparison, a Deimos "month", at 30 hours 18 minutes, is more normal.

To an observer on the surface of Mars near the equator, Phobos would rise in the west and set in the east some 4 hours 15 minutes later, during which time it would go through more than half its cycle of phases from new to full. The interval between each appearance would be just over 11 hours. Deimos, however, would rise in the east and creep slowly across the sky, to set in the west some 60 hours later, having passed through its phase-cycle twice [5].

Neither passage would be particularly dramatic. Deimos would be about as bright as Venus appears from Earth overall, although larger and dimmer. Phobos, although several magnitudes brighter, would still be less of a spectacle than even a thin crescent moon seen from Earth. Because of their low equatorial orbits, Phobos would not be visible at any time north or south of latitude 69 degrees. Deimos could not be seen polewards of 82 degrees [6].

Secular Acceleration of Phobos

In 1945, the American astronomer B. P. Sharpless noted peculiarities in the orbit of Phobos, and concluded that the inner moon was gradually spiralling closer to Mars, and would eventually strike the planet. In celestial mechanics, a continuous, non-periodic change in the characteristics of an orbit is called a "secular change". In 1959, the Soviet astrophysicist Iosif Shklovsky suggested that if the Sharpless calculations were correct and Phobos was indeed displaying secular acceleration, then some force or influence had to be pulling the moon out of orbit. The two main contenders were tidal friction and atmospheric drag. Shklovsky felt that mathematical considerations ruled out the former, so he favoured the latter.

Unfortunately, calculations made in 1954 by the astronomers Kerr and Whipple had suggested that the Martian atmosphere at the orbital height of Phobos was one hundred thousand times too diffuse to account for the secular acceleration. Shklovsky, however, reasoned that the calculations had been made with a solid, rocky Phobos in mind. Atmospheric drag could account for the phenomenon if Phobos had a density no greater than 10^{-3} gr/cm³ (one thousandth the density of water). This could only be the case if Phobos were an artificial, hollow satellite launched into orbit by an advanced technical civilization on Mars some hundreds of millions of years ago! Despite the fact that such a vast edifice would have weighed hundreds of millions of tons, Shklovsky insisted that the notion "merits serious consideration." [7].

In a later comment on the sceptical reactions to his theory, Shklovsky pointed out that "not one scientific argument was advanced against the hypothesis." [8]. However, in more recent years the original Sharpless calculations have been called into question, and a thorough analysis of Phobos observations by Mariner 9 has indicated that, although there is a definite secular acceleration, it is at least a factor of three smaller than Sharpless calculated. Telescopic observations have independently confirmed this [9].

Even at this reduced rate of secular acceleration, Phobos is likely to be pulled out of orbit within about one hundred million years, unless tidal stresses first pull the moon apart, thereby creating a Martian ring-system.

It is now accepted that the principal, if not the only, cause of the secular acceleration is tidal drag. Since Mars has no seas, the tides are raised within the solid body of the planet. The feeble pull of Phobos causes a slight "bulge" in the Martian crust which follows the moon around its orbit, though lagging behind. The very slight additional gravitational pull from this bulge slows Phobos down very slightly, causing the moon to spiral down into an almost imperceptibly closer, and therefore faster, orbit.

Mariner 7

The first opportunity to study the Martian moons by spacecraft came with the Mariner Mars 1969 Project, one of the objectives of which was to determine the physical size and reflectivity of both moons. Although Deimos was not seen, Phobos was positively identified on three of the Mariner 7 far-encounter images, the best being No. 91. The image of Phobos was barely seven picture elements wide, but the moon was clearly irregular in shape and much larger than Kuiper had predicted in 1956. B. A. Smith of New Mexico State University calculated Phobos to have a limb-profile of 18 by 22 km, and an albedo of 0.065, making it the darkest known body in the Solar System [10]. He also suggested, on the basis of the Mariner data, that Phobos may originally have been an asteroid captured by Mars (a subject which is discussed in detail below).

Mariner 9

In late September 1971, astronomers on Earth recorded a yellow cloud developing in the mid-southern latitudes of Mars. By the middle of November, when Mariner 9 became the first spacecraft to enter Martian orbit, the planet was almost entirely obscured by the most widespread dust-storm ever observed. Unable to begin the planned mapping of Mars until early in 1972, the Mariner controllers were forced to adopt contingency plans which gave high priority to the first detailed observations of Phobos and Deimos.

During its active lifetime, Mariner 9 obtained 32 high-resolution pictures of Phobos and nine of Deimos. Over one hundred additional lower-resolution photographs, many obtained prior to orbital insertion, greatly improved knowledge of the orbital ephemerides of both moons. The highest resolution pictures, from a range of little more than 5,000 km revealed Phobos and Deimos to be dark, irregularly-shaped, heavily cratered bodies. Resolution was good enough to show features as small as 200 metres across, and Shklovsky's fanciful notion was finally laid to rest.

In total, Mariner 9 mapped about 70 per cent of Phobos and 40 per cent of Deimos at one-kilometre resolution. Since the spacecraft's orbit was entirely within that of Deimos, only one side of the smaller moon was ever visible.

Unlike the larger bodies of the Solar System, Phobos and Deimos are not even roughly spherical in shape. Allowing for various missing chunks, the Mariner 9 photographs showed both to be "triaxial ellipsoids." Phobos has principal diameters of approximately 27, 21 and 19 km respectively. Analysis of the less-complete Deimos imagery indicated a remarkably similar shape, and diameters of 15, 12 and 11 km [11]. Profile views of the limbs of both moons display large indentations which are clearly not craters. The effects of high-velocity meteoroid impacts on small bodies has been simulated in laboratory experiments, where aluminium pellets have been fired at crystal glass spheres at varying velocities. Lower-energy impacts leave crater-like scars on the targets. Higher-energy impacts gouge out large craters, but – more significantly – they also generate shock waves which knock large chunks off the targets. This "spallation" is concentrated on the face of the sphere opposite the point of impact, and often the entire outer layer of the target is knocked off, leaving an irregular inner core. These inner cores have been found to bear a striking resemblance to Phobos and Deimos, and this may perhaps explain why the two moons have very similar shapes [12].

Although neither moon is very massive, it had been expected that both were close enough to Mars for tidal forces to be effective. If a small body is set spinning in the vicinity of a larger body, tidal friction eventually brakes the rotation rate of the smaller body until it is synchronous with the rotation rate of the larger body, as in the case of Earth's moon. By tracking individual surface features on Phobos and Deimos during different orbits, Mariner 9 data analysts were able to confirm that both moons are "tidally locked", and therefore always display the same face towards Mars. In each case, the longest axis points towards Mars, with the intermediate axis lying in the orbital plane.

The time required for synchronous rotation to be achieved is affected by the distance between the bodies. The closer the satellite, the shorter the spin-down time. It has been estimated that Deimos should have achieved synchronous rotation within one to one hundred million years. For Phobos, being much closer to Mars, between ten thousand and one million years would probably have been enough. These calculations place lower limits on the time elapsed since the moons were last set spinning. This in turn gives an indication of how long ago the

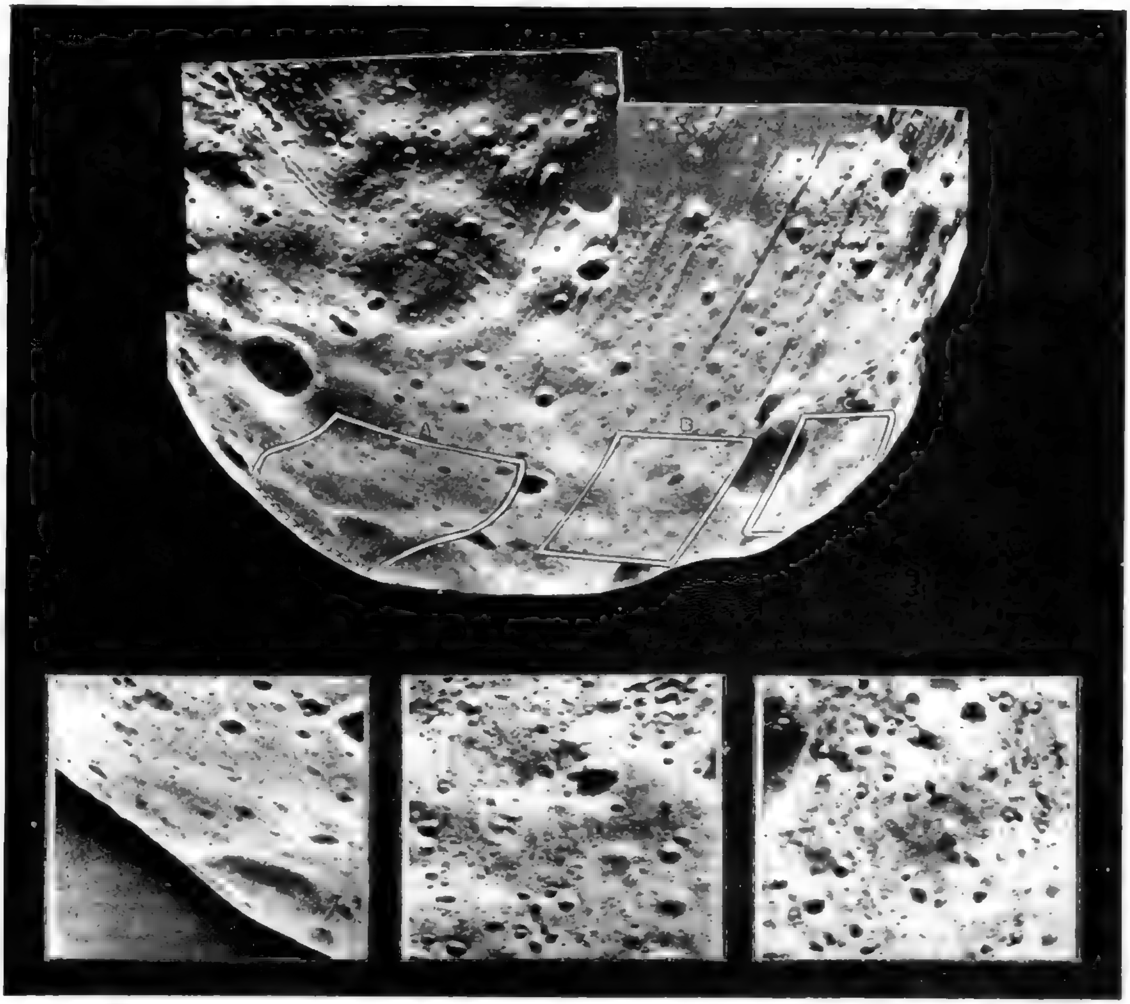


Fig. 2. One of many Viking 1 photo-mosaics obtained in February, 1977. The large picture shows numerous "groves" (many with a pitted or beaded appearance). The large crater to the lower left has dark material on its floor. Objects less than 10 metres across are visible in the smaller pictures.

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last large meteorite impacts (powerful enough to impart spin to the moons) occurred [13].

Before Mariner 9 reached Mars, the nature of the surfaces of bodies as small as Phobos and Deimos was very much open to debate. Because of the very weak gravity, a meteorite impact would blast most crater ejecta out into space. It was not known whether craters on the moons would have the familiar raised rims, or merely be pockmarks in the surface. Mariner 9 revealed a profusion of recognizable craters down to the limits of resolution. Only such gravity-induced features as central peaks and ejecta-blankets were missing.

The two largest craters on Phobos were named Hall and Stickney, after the astronomer and his wife (born Angeline Stickney). At six and ten kilometres in diameter, respectively, they represent huge scars on the face of the inner moon, and probably came close to shattering Phobos completely. Stickney's diameter is about 45 per cent of the "average diameter" of Phobos. An equivalent crater on the Earth would swallow up the entire North American continent!

The largest craters on Deimos viewed by Mariner 9 were named Voltaire and Swift. The former is a subdued two-kilometre structure, obviously much older than the latter which is half the size but has a conspicuous rim.

Both moons appear to be virtually saturated with craters. Dr. James B. Pollack of Ames Research Center, California, argued that both are at least 1,500 million years old and may, in fact, date back to the birth of the Solar System, some 4,600 million years ago [14].

Another question apparently answered by Mariner 9 concerned the consistency of the moons. Were they composed of solid rock, or were they merely loose agglomerations of rubble and dust, bound together by gravitational forces? The discovery of the craters in the Mariner pictures did not automatically rule out the latter possibility, according to some theories [15], but the appearance of sharp edges and "missing lumps", and the strong evidence of spallation, seemed to prove that both moons are structurally rigid. Calculations based on the effects of the Stickney impact produce the conclusion that Phobos and Deimos are composed of well consolidated material which is at least as strong as fractured and jointed rocks [16].

Whatever the internal structure of the moons, clear evidence came to light, during the operational lifetime of Mariner 9, of a surface layer of fine-grained material (regolith) on both. In 1971, Benjamin H. Zeller of the University of Arizona managed to measure the polarization of sunlight scattered from the surface of Deimos. The surface of the moon polarized light in a manner characteristic of dark powder rather than rock. Mariner 9 analysis of the light-scattering properties of both moons suggested homogeneous layers of regolith. No patches of exposed rock were noted on either moon [17].

Mariner 9 measurements of infra-red radiation from Phobos before and after the moon's passage through the shadow of Mars complemented the light-polarization studies. After

emerging from the shadow, Phobos was seen to heat up very rapidly, indicating a surface layer with very low thermal conductivity. This is a characteristic of a fine-grained regolith.

It is not fully understood how small bodies with negligible gravity fields hold on to their regoliths, although two theories are favoured. When a meteoroid strikes the surface of Phobos or Deimos, material is blasted out of the crater at various speeds. Most of it exceeds the very low escape velocity and is lost, but a proportion of it is ejected at a low enough velocity to settle back on to the surface of the moon and gradually build up a regolith.

Where an impact blasts material away from Phobos or Deimos, much of it remains trapped in Martian orbit, where some can later be "swept up" again by the moon from which it originated. Thus, Phobos and Deimos may be building up their regoliths by recovering material previously lost through meteoroid impacts [18].

Viking

After the oribital reconnaissance of Mars by Mariner 9, the inevitable next step was an attempted landing. Launched in August and September 1975, the two identical Viking spacecraft reached Mars in June and August 1976. The Viking Project will, quite understandably, be remembered primarily for the two virtually flawless landings and the resulting photographs and observations on the surface of Mars. (See *Spaceflight* 1976, pp. 84, 124, 158, 211 and 241). But while the Landers were making history and capturing the headlines, the twin Orbiters were carrying out a thorough and detailed survey of the planet and its two moons. Indeed, the satellite observations have resulted in the closest encounters and highest-resolution photography of all orbital planetary exploration to date.

The first satellite picture was of Phobos on 24 July 1976, by Orbiter 1. During the Viking Primary Mission (20 June–15 November 1976) the two Orbiters acquired about fifty photographs of the moons, thus completing the medium resolution Phobos coverage (down to about 200 metres) and extending the Deimos coverage. As with Mariner 9, both Vikings orbited within the orbit of Deimos, and were thus denied a view of the "far-side" of the outer moon.

Because improved camera techniques increased sensitivity to small-scale scene variations, the Viking images of Phobos and Deimos have a higher surface resolution than Mariner 9 pictures from the same range. In addition, both Vikings often approached within the 5,000 km range which was the closest achieved by Mariner. One particularly close encounter occurred during Viking 2's 38th orbit, when the spacecraft came within 880 km of Phobos. Surface details as small as 40 metres (including a series of mysterious grooves or fractures) were visible. In order to achieve a sharp picture at such a close range, it was necessary to compensate for the motion of Phobos relative to the spacecraft during the exposure. A technique was successfully achieved which slewed the camera at a rate of 0.25 degrees per second. Without this slewing, image smear would have reduced resolution to a blurred 250 metres [19].

Several images were obtained showing a crescent Phobos, with the remainer of the moon faintly illuminated by reflected Mars-shine. These images were particularly useful for determining the size and shape of Phobos.

The twin-camera system on each Viking Orbiter enabled simultaneous pictures to be taken showing a moon and the star background. Thus, the position of each moon in space could be assessed with much greater accuracy than before: an ultimate accuracy of a few tenths of a kilometre was predicted.

Experimental studies carried out in 1976 showed that very close fly-bys of both moons could be obtained with only small changes in the orbits of the two Viking Orbiters. The orbital period of each spacecraft was therefore altered slightly so as to become an integral multiple of the orbital periods of the moons. As a result Orbiter 1 flew within 80 km of Phobos in February 1977, and within 290 km in May of the same year. Orbiter 1 also viewed Deimos from 1,500 km in October 1977; but the crowning achievement was the steering of Orbiter 2 within 26 km of the surface of Deimos on 15 October 1977.

A special team of Viking scientists and engineers was formed to take advantage of the close encounters. Their primary objectives were: (a) to determine satellite masses and volumes within ten per cent; (b) to obtain very high resolution (10–20 metre) photographs; and (c) to obtain infra-red coverage of both moons at 1–2 km resolution.

Phobos Close Encounters

The manoeuvres which led to the first ultra-close Phobos fly-by were carried out in late January and early February 1977. Orbiter 1 was nudged into a modified 23 hour orbit which was three times the period of Phobos. This allowed the spacecraft to make a number of approaches within 300 km during a two-week period in mid-February, with the closest approach occurring on 20 February [20].

These close encounters of the Martian moons required full exploitation of the camera slewing technique developed in 1976, and the highest degree of spacecraft navigational skills ever displayed in NASA's unmanned exploration programme. Before the encounters could be attempted, picture sequences of Phobos against the starry background were carried out to make more accurate predictions of the exact positions in space of Phobos and Viking. Even so, the first close-encounter picture sequence showed that position-errors were building up more quickly than had been anticipated. Phobos was obviously more massive than had been expected. New estimates were fed into the spacecraft computer. As a result, out of 150 close-encounter pictures, only 25 suffered significant data loss.

The picture sequences obtained during both the February and May 1977 close encounters were a triumph. The improved resolution (down to about 10 metres) revealed small hummocks; craters with bright ejecta blankets (confounding previous opinions); dark material in the floors of some craters, and crater densities close to saturation limit. Two long linear ridges were mapped.

However, the most intriguing features on Phobos – revealed in excellent detail by Orbiter 1 – turned out to be the so-called "grooves". These are long, linear striations or cracks which appear over much of the surface of the moon. They cross over large, ancient craters (Hall, for example) but are interrupted by more recent, well-defined craters. This indicates an origin substantially later than that of Phobos itself. With one possible exception, these grooves were not seen by Mariner 9, since an image resolution of better than 70 metres is necessary to reveal them.

Three main hypotheses have been put forward to explain them. One theory attributes them to fracturing caused by increasing tidal stress as Phobos moves closer to Mars. Supporters point out that one very prominent series of grooves is arranged around the tidal equator of Phobos, as if the moon is being "stretched" along its longest axis by the pull of Mars [21].

A second theory suggests that Phobos suffered severe fracturing (evidenced on the surface by the grooves) during the hypothetical capture of the satellite by Mars [22].

A further theory attributes the grooves to a large, nearly catastrophic cratering event, and it is this hypothesis which the available evidence tends to support [23]. The sketch map (prepared by Peter Thomas of Cornell University) shows the distribution of the grooves in relation to Stickney crater. (The apparent lack of grooves to the west of the crater is explained by the lower resolution photography of the area between 70 degrees and 160 degrees West).

It is strikingly clear that grooves radiate out in all directions from Stickney and converge towards a region near 270 degrees West, where they die out. This area, although not exactly 180 degrees away from the centre of Stickney, is on the opposite

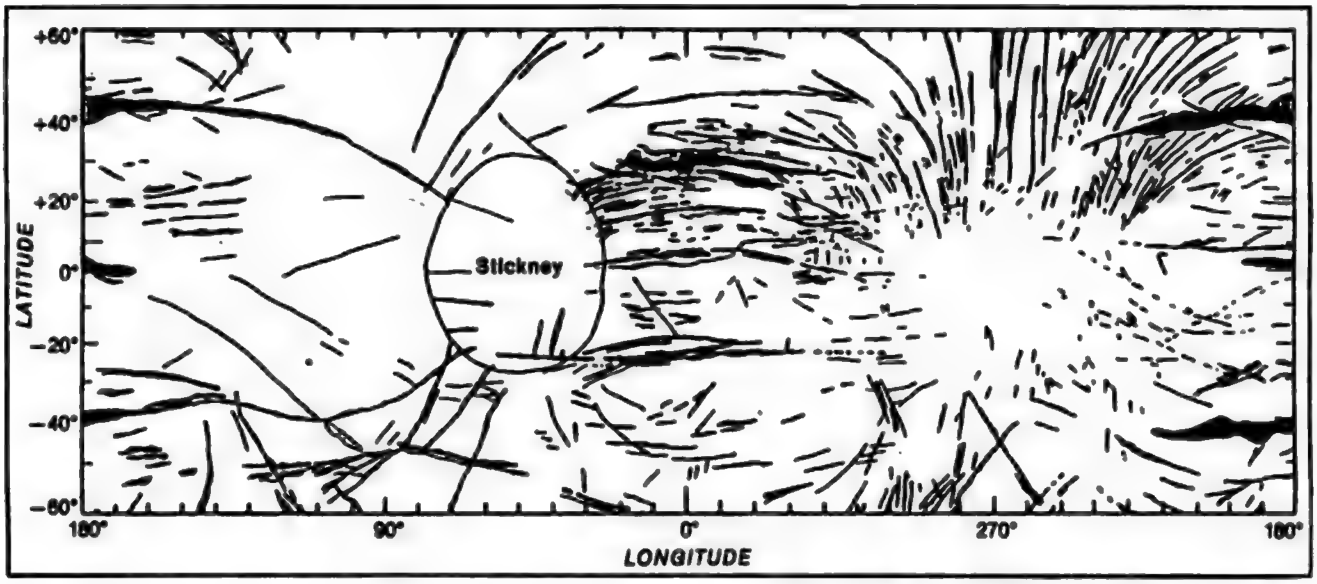
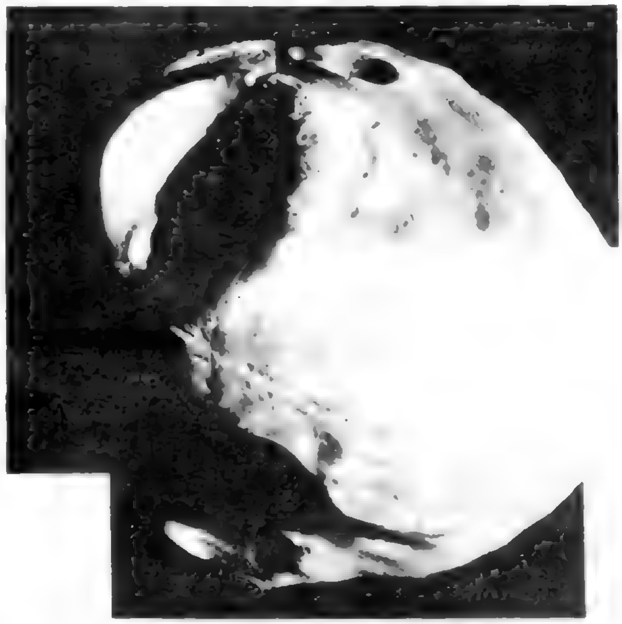


Fig. 3. This diagram—prepared by Peter Thomas, Cornell University, New York—shows the relationship between Stickney crater and the grooves of Phobos. The grey areas represent broad complex grooves. The "bare" region to the west (left) of Stickney was imaged at a lower resolution than the area to the east.



Right, Phobos photographed at a range of 380 miles (612 km) on 19 October 1978 by Viking Orbiter 1. The photomosaic shows the front side of Phobos which always faces Mars from about 10 degrees below the equator with north at the top. Stickney, the largest crater—about 6 miles (10 km) across—is at the left near the morning terminator. Linear grooves coming from and passing through Stickney appear to be fractures in the surface caused by the impact which formed the crater.

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side of the decidedly non-spherical moon. On average, the grooves are 100 to 200 metres wide and 10 to 20 metres deep, but they are best developed (up to 700 metres wide and 90 metres deep) adjacent to Stickney. At the antipodal point they taper to less than 100 metres in width, and gradually peter out.

The pattern of the grooves suggests strongly that they are connected with the formation of Stickney, and may be surface manifestations of deep-seated fractures within Phobos. Most of the grooves have a beaded or pitted appearance, rather like chains of small, connected craters. Some have broad, irregular sections containing hummocky terrain which seems to rise above the level of the surrounding surface. A few straight-walled sections appear to have slightly raised rims.

The most obvious explanation for the beaded appearance is the existence of loose material filling deep cracks. This may simply be surface material which has sifted down into the cracks like sand slipping down into an egg-timer. However, such a simple explanation does not fully take into account the very weak gravity of Phobos (only one-thousandth that of the Earth) [24].

An alternative explanation assumes that Phobos is composed of low density material containing many volatiles, including water. (*This is discussed in more detail below.*) The Stickney impact would have caused phenomenal heating which may have released large quantities of water in the form of steam. The steam would have escaped along the fractures, blowing away surface material to form the chains of crater-like pits, and possibly the hummock features as well [25].

The age of the grooves can be estimated from the density of superimposed impact-craters, and appears to be in excess of 3,400 million years. Available evidence suggests that the Stickney impact may have been almost sufficient to shatter Phobos, and certainly sufficient to cause a network of deep-seated fractures, evidenced on the surface by the grooves.

Deimos Close Encounters

During October 1977, the orbital period of Viking Orbiter 2 was changed to 24.2 hours, giving it a five-to-four orbital commensurability with Deimos. This enabled a series of close encounters (within 1000 km) to occur at five-day intervals beginning on 5 October. Before the sequence was ended, late in the month, the 26 km encounter was achieved on 15 October [26].

Among the major findings of the Mariner 9 and early Viking photography of Deimos was the discovery that, unlike the uniformly dark Phobos, the surface of the outer moon has a number of bright patches which are up to thirty per cent brighter than the average albedo. In addition, Deimos appeared to be significantly smoother than Phobos at high resolution, which was puzzling, since both moons were known to have approximately equal crater densities at 500 metre resolution.

The 26 km encounter has revealed details in the northern hemisphere of Deimos as small as two metres across. The

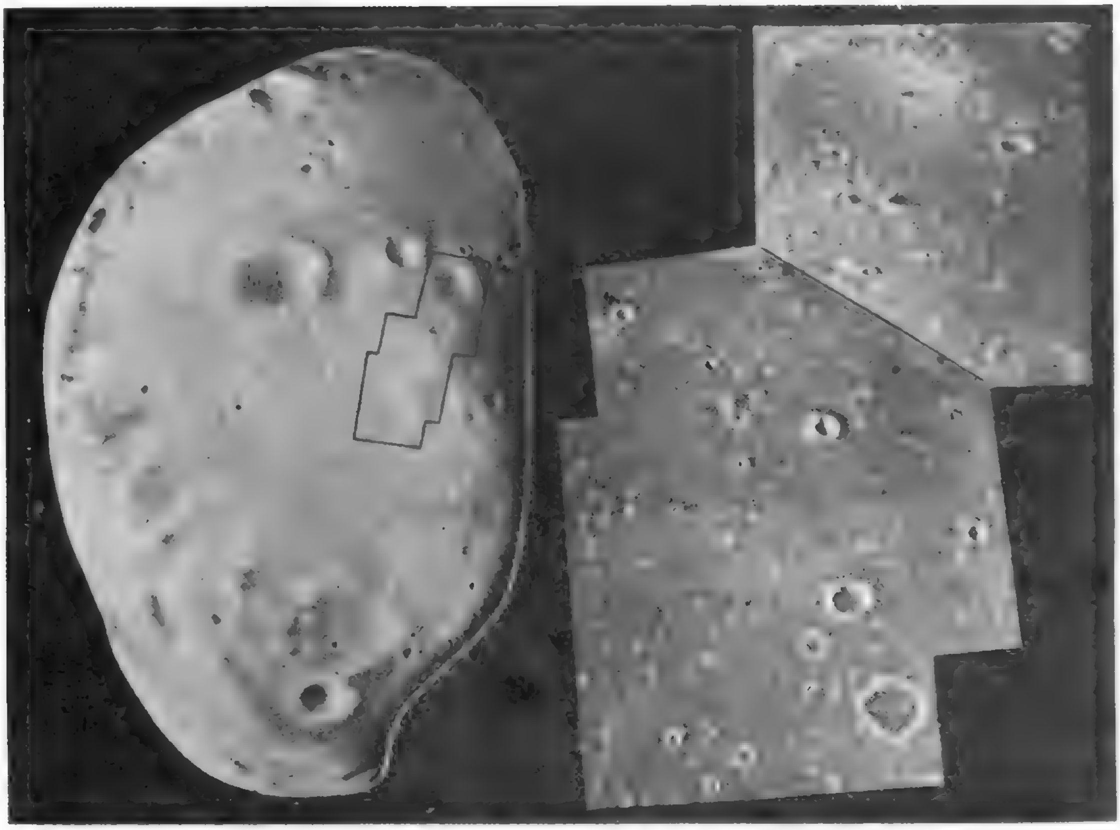

Fig. 4. DEIMOS fron Viking 2 in October 1977. At 310 miles (500 km) Deimos displays several large, degraded craters and bright albedo patches. The north pole is to the right of the large crater (upper centre). The mosaic at right covers only 1.8×1.2 miles (3×2 km) and reveals hundreds of tiny craters almost drowned by a thick surface dust-layer. House-sized boulders litter the surface. Best resolution is about 6.5 ft (2 m).

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bright patches appear to be deposits of fine-grained material (possibly crater ejecta) which has partially filled many of the smaller craters. The surface of Deimos is actually as crater-scarred as that of Phobos, but only the larger craters are visible through the thick blanket of regolith. The close encounter images also reveal that the surface of the moon is littered with numerous isolated objects which appear to be house-sized boulders. These are apparently more common on Deimos than Phobos, but the best Phobos images admittedly have a coarser resolution.

It is puzzling why Deimos seems to have retained a much thicker regolith than Phobos. Obviously the retention process is much more efficient. One possibility is that the surfaces of the two satellites have different mechanical properties, so that impacts on Deimos would produce a larger percentage of low-velocity ejecta which would fall back to the surface. Alternatively, the very close proximity of Phobos to Mars may make it easier for ejecta to escape not only from the surface of the inner moon, but even from its orbit. This would give Deimos a better chance than Phobos of sweeping up and recapturing lost material from Martian orbit, since orbiting debris would be more plentiful farther out from Mars.

None of the Deimos close encounters have revealed any grooves on the outer moon. The probable explanation is the absence of any known cratering event powerful enough to have fractured the moon. The largest crater on the visible side of Deimos is 3 km across. There is a large indentation (ten kilometres wide and two deep) dominating the south polar region, but it does not have crater-like characteristics and may, in fact, be evidence of the fragmentation of Deimos from a much larger body.

Following the close encounters, estimates of the size of Deimos have been revised from 1,000 cubic kilometres to the larger figure of 1,200–1,500 cubic kilometres. One implication of this increase is that the true geometric albedo must also be lower (0.05–0.06) [27].

Composition and Origin of Phobos and Deimos

Without doubt the most intriguing and controversial question about Phobos and Deimos is that of their origin. Theories tend to fall into two main schools: capture and accretion. The capture theory suggests, essentially, that Phobos and Deimos were asteroids (or fragments of a larger asteroid) which were captured by Mars. The accretion theory regards the satellites as collections of material left over from the formation of Mars which condensed into the present irregularly-shaped bodies.

The capture theory is superficially attractive: in the Mariner and Viking pictures, both moons resemble artists' impressions of "typical asteroids". Yet it is by no means obvious how captured asteroids could have entered such neat, regular orbits around Mars. The orbit of Phobos is almost circular and inclined at a mere 1.1 degrees to the Martian equator, while that of Deimos – also virtually circular – has only a slightly greater inclination at approximately 1.8 degrees. Opponents of the capture theory argue that it would be too much of a coincidence for two captured bodies to display such orbital characteristics; and that elliptical, higher-inclination orbits would have been the almost inevitable results of capture.

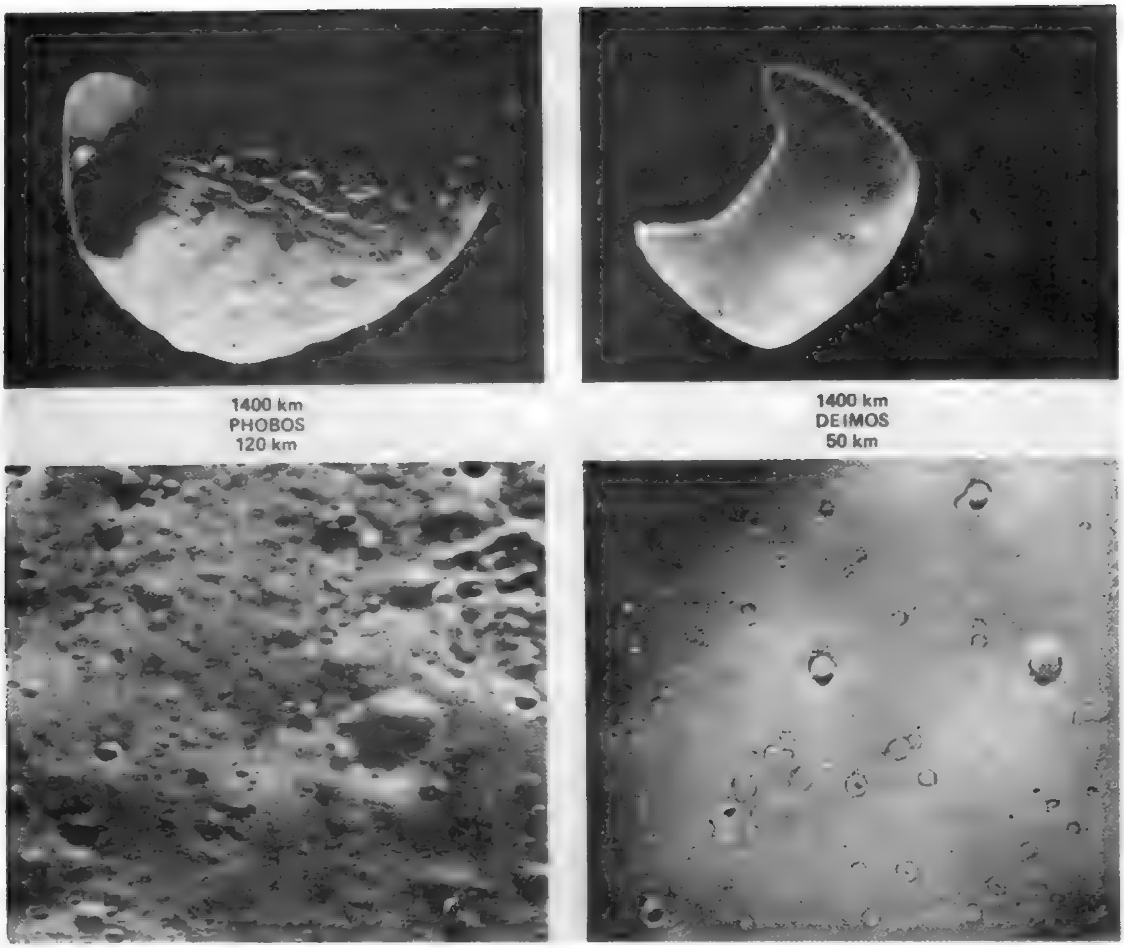

Fig. 5. A comparison between the surfaces of Phobos (dominated by Stickney crater) and Deimos. At lower resolution, Deimos appears much smoother, with fewer craters and no grooves. Higher-resolution pictures show both surfaces to be heavily cratered, with the Deimos craters wholly or partially filled with dust.

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The accretion theory also has its difficulties. It has been argued that if the moons had accreted from "Martian leftovers", they would have been more spherical. This objection can perhaps be parried by reference to the spallation experiments carried out on spherical targets (discussed earlier). However, a further difficulty is that the moons simply do not resemble Mars. They are a different colour and have albedos which are less than half that of Mars, which suggests a different composition and origin.

In order to settle the question of origin, it will be necessary to learn what Phobos and Deimos are made of. The most likely choices are basalt (a dark, igneous rock) and carbonaceous chondrite material (dark, crumbly rock of which a particular type of meteorite is composed).

Basalt composition would indicate that the moons are fragments of a much larger body which once underwent internal heating and melting (perhaps a large moon which formed in the vicinity of Mars and subsequently shattered in some unexplained catastrophe [28].

Carbonaceous chondrite material is essentially the primitive stuff of the primordial Solar System. Examples which have fallen to Earth as meteorites have been found to contain high concentrations of volatile materials (water, gases, hydrocarbons, and some organic-like substances). They are classified as Type 1, Type 2, or Type 3, depending on the quantity of volatile materials. Recent research strongly indicates that this primitive material could not have formed as close to the Sun as Mars [29], and most probably originated in the outer asteroid belt. This is almost certainly true for the Type 1 carbonaceous chondrites which have the highest volatile content [30].

The two Viking Orbiters were engaged, during the close encounters, to conduct a series of experiments designed to determine the density and composition of each moon, in a concerted attempt to solve the mystery. The most direct method of determining density is to estimate mass and volume as accurately as possible. The volumes of the moons were inferred from estimates of sizes and shapes which the close-range photography had made possible. The procedure involved taking many "missing lumps" into consideration. The volume of Phobos was calculated to be 5,000 ± 900 cubic kilometres [31]. Since one hemisphere of Deimos has not been viewed properly, a number of calculated guesses are included in the Deimos estimate of 1,350 ± 150 cubic kilometres [32].

The mass of each moon was estimated by carefully analyzing the minute changes in the Viking trajectories as they passed Phobos and Deimos, and the subsequent changes in the spacecraft orbits. Although these estimates are subject to certain inaccuracies, density figures have been obtained. The estimate for Phobos is 1.9 ± 0.6 gr/cm^3 [33]. Two years of further data analysis and refinement has not (at the time of writing) resulted in any modification of this original figure. The preliminary estimate for Deimos is only 1.6 ± 0.6 gr/cm^3 but confidence in this figure is somewhat lower and detailed analysis of Deimos volume and mass estimates is continuing [34]. It is probable that the Deimos figure is rather too low, but the clear overall impression is that the density of the moons does not greatly exceed the Phobos "middle" estimate of ~2 gr/cm^3. This effectively rules out basalt (which has a density close to 3.0 gr/cm^3) as a chief constituent.

Spectroscopic analysis in the infra-red and ultra-violet wavelengths by Earth-based astronomers and by Mariner 9 and the Vikings has produced further evidence to support the conclusions of the density experiments. The reflectance spectrum of Phobos bears a striking resemblance to those of the asteroids Ceres and Pallas. Extensive research has already been carried out to determine the composition of Ceres, including the comparison of the spectral "signature" of the asteroid with those of various meteorites of known composition. These studies strongly suggest that Ceres is composed of carbonaceous chondrite material, and the most recent research now shows a good match between the reflectance spectra of Phobos and Ceres [35].

Further observations were made from the surface of Mars by the Viking 2 Lander at Utopia. On its 48th day on Mars, the Lander obtained seventeen images of Phobos crossing the pink sky. Various different wavelengths were employed. The results were compared with spectral reflectivity readings for powdered samples of basalt, carbonaceous material and several other substances. Of all the materials tested, only the carbonaceous chondrites displayed spectral characteristics consistent with those of Phobos, as measured by the Viking camera [36].

The overall results of these experiments tend to rule out basalts and the denser Type 3 chondrites. Although Type 2 chondrites are still in the running, the weight of the evidence seems to favour Type 1 material. If this conclusion continues to hold up under further analysis of the available data, then it would be difficult to avoid the conclusion that Phobos and Deimos originated in the outer asteroid belt and were captured at a later stage by Mars.

How Were Phobos and Deimos Captured?

Despite the very strong evidence in favour of the capture hypothesis, the neat equatorial orbits of Phobos and Deimos have always been a major stumbling block to its acceptance. However, new studies have contributed substantially to the debate and have perhaps explained how captured asteroids could achieve regular orbits.

Although much controversy surrounds the theories which attempt to explain the origin of the Solar System, it is generally accepted that the Sun and planets condensed out of a vast primordial nebula of dust and gas. In the early history of the Solar System after the planets had accreted, there would still have been large quantities of residual dust and gas remaining. According to Professor Donald Hunten of the University of Arizona, dense concentrations of this nebular material would have congregated in the form of "protoatmospheres" around the newly-formed planets [37]. Although planetary-gravity-fields would have acted as focal-points for this material, Hunten considers that the protoatmospheres would have dissipated quickly without the external pressure of the solar nebular to hold them together around the planets.

Hunten suggests that some wandering asteroids encountered Mars and were sufficiently decelerated while passing through the Martian protoatmosphere to be captured. The initial orbits of these captured moons would have been highly elliptical, but continued atmospheric drag gradually reduced the eccentricities and inclinations of the orbits until they had become circular. The relatively dense protoatmosphere around Mars then dissipated; no further evolution of the orbits took place (except for tidal effects); and Phobos and Deimos were left in the neat, equatorial orbits which we see today.

Presented in this crude form, Hunten's theory clearly requires further explanation to seem credible. For instance, how did the wandering asteroids reach Mars, and why were they captured? Hunten suggests that either the gravity of Jupiter, or gradual drag caused by passage through the dust and gas of the solar nebular, would have caused many asteroids to spiral inwards towards Mars. No element of luck (either critical speed or critical timing) is required: many asteroids presumably encountered Mars at the wrong relative speed and either passed by, or struck the planet. Phobos and Deimos were two which entered the Martian protoatmosphere at the appropriate speed for atmospheric drag to effect capture.

The second vital question is exactly how the orbits of the captured asteroids were circularized. A study of artificial Earth satellites is helpful in understanding this phenomenon. If a satellite travelling in an elliptical orbit around a planet dips into the planet's atmosphere at its perigee, or low-point, then the orbital velocity will be reduced by atmospheric drag. The most pronounced effect on the orbit is a substantial, lowering of the apogee, or high-point, of the orbit (with only a slight accompanying lowering of the perigee). Gradually, each dip into the atmosphere will reduce both the eccentricity and the inclination of the original orbit. In the case of Phobos and Deimos, repeated dips into the denser layers of the protoatmosphere could have rendered the original orbits relatively circular and equatorial.

The third essential question is why the Martin protoatmosphere dissipated at just the right time to prevent complete orbital decay of Phobos and Deimos. Hunten assumes that had it not dissipated, the asteroids would certainly have been decelerated out of orbit. The point is that many other captured asteroids may have actually suffered this fate before the protoatmosphere dissipated.

Hunten's protoatmosphere would have had a substantial density as far out from Mars as three to six planetary radii. Such an atmosphere, unless subjected to external pressure from the solar nebula, would have been very unstable and prone to rapid escape from a planet with relatively weak gravity.

Since the solar nebula is not present today, something certainly caused it to disappear. It is well known that many young stars pass through a phase called the "T Tauri stage", when they eject vast quantities of matter and energy in a relatively short time. Such a vast outpouring of energy from our Sun (a very intense version of the solar wind, known as the "T Tauri wind") could easily have blown all the excess dust and gas out of the Solar System, thus allowing the Martian protoatmosphere to escape into the near-vacuum of space. Hunten himself, however, somewhat prefers the idea of the nebula material falling inwards to the Sun (a form of gravitational collapse) [38]. The nebula may have eroded away in layers or "shells". Even if the whole process was lengthy, it could have been rapid at any one location such as the vicinity of Mars.

Recent research by a team at the Ames Research Center, California, led by Dr. James Pollack, has suggested a capture hypothesis rather similar to Hunten's, though differing in several respects. Pollack's team suggests that a single parent asteroid was captured by gas-drag in a primordial Martian nebular [39]. (The suggested nature and origin of this nebula differs somewhat from the Martian protoatmosphere envisaged by Hunten). Stresses caused by rapid deceleration through the nebula caused the parent asteroid to fragment. The two major fragments (Phobos and Deimos) were subjected to continued gas drag which circularized their orbits. Eventually, the moons were circling Mars at the same speed as the material in the nebula, so that in the absence of further drag, little further orbital evolution occurred. Then the nebula dissipated. The two moons gradually separated, perhaps assisted by large meteorite impacts. Tidal forces acted on both moons, but particularly on the larger Phobos which gradually drifted closer to Mars. Pollack claims support for this scenario from the measured degree of secular acceleration experienced by Phobos. This gradual Marsward movement suggests that, 4,600 million years ago, Phobos would have been very much closer to the present position of Deimos. Pollack suggests that such close proximity of the two moons in the early history of the Solar System lends weight to the suggestion that Phobos and Deimos may once have been part of the same parent body.

Conclusion

The recent capture theories clearly deserve further investigation and research; but in the light of the Viking findings, it is perhaps now incumbent upon the opponents of the capture hypothesis to show good reason why their suggestions are still worthy of serious consideration.

Little over a century ago, Phobos and Deimos were mere points of light, lurking in the Martian glare. One hundred and three years after their discovery, many of their secrets have been revealed and their surfaces examined with greater clarity than any other celestial body save our own Moon, Mars itself, and Venus. It is reasonable, perhaps, to consider these tiny worlds – which may consist of the pristine material of the Solar System – as a bridge between the inner and outer parts of the Sun's family. The next logical step, which will surely come in due course, is a sample collection mission, which might well present man with his first opportunity to touch the asteroids.

Acknowledgements

I am indebted to a number of individuals who greatly assisted my preparation of this article. Dr. Thomas Duxbury of the Jet Propulsion Laboratory, California, provided the photographs, as well as much valuable information. I am also grateful to Professor Donald Hunten of the University of Arizona and Dr. James Pollack of the Ames Research Center, California, for helping me to understand some of the finer points in their recent papers on gas-drag capture.

I wish also to acknowledge the work of the many scientists, researchers and writers (named in the References) whose contributions to numerous scientific publications have provided much of the background information in this article. I must stress that any errors or ambiguities arising from my summarizing of their findings are my responsibility and not theirs.

Finally, I wish to acknowledge my debt to the engineers and scientists of the Viking and Mariner 9 missions (managed by the NASA Office of Space Science), without whose technical expertise most of the information in this article simply would not have been available. I am pleased to place on record my admiration for the near-miracles which they have performed.

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THE POLYOT MISSIONS

By Phillip S. Clark

Introduction

In November 1963 and April 1964 the Soviet Union launched the two spacecraft in the Polyot programme. The two satellites tested a spacecraft manoeuvring system, although the subsequent use of the technology has not been identified with certainty. This article will review the known information about the Polyot craft and look at the various suggestions which have been made for the follow-on operational flights of the Polyot system.

Launch Announcements

Polyot 1 was launched on 1 November, 1963 and the *Pravda* article covering the launch [1] said that space vehicles "were being developed in the Soviet Union which can be manoeuvred widely in all directions during orbital flights."It would be impossible to give the full launch announcement here, but some extracts are given below:

(1) "Polyot 1 is equipped with special apparatus and a system of auxiliary motors which ensure that it is kept stable and enable it to be highly manoeuvrable in circumterrestrial space."

(2) "The space vehicle has been put into an initial orbit having an apogee height of 592 km and a perigee height of 339 km."

(3) "Polyot 1 has performed important lateral manoeuvres, varying the plane of the orbit, as well as manoeuvres in height, and has entered a final orbit having an inclination to the plane of the equator of 58° 55′, with an apogee of 1437 km and a perigee of 343 km."

It should be noted that the initial orbital inclination for Polyot 1 was not included in the launch announcement.

When Polyot 2 was launched on 12 April, 1964 no further details of the craft emerged, but the launch announcement [2] gave the following information:

(1) "*After separation from the carrier rocket*, and ballistic flight, Polyot 2 was put into an initial orbit by means of a special motor, and in conformity with the predetermined programme carried out numerous manoeuvres in various directions. As a result of performing one of these manoeuvres in the region of the equator the space vehicle considerably changed the angle of inclination of the plane of the orbit."

(2) "After performing the whole programme of manoeuvres, the final orbit of Polyot 2 has the following parameters:

angle of inclination to the plane of the equator	58.06°
apogee height	500 km
perigee height	310 km"

It should be noted that there was no initial orbit given at all for Polyot 2. If we work only on the Soviet-announced data it is impossible to calculate the actual delta-Vs involved in the flights. It should also be remembered that Polyot 2 (and, one assumes, Polyot 1) put itself into orbit after separating from the launch vehicle, and therefore some of the delta-V capacity is hidden in this unknown manoeuvre.

The Orbital Manoeuvres

Table 1 shows the orbital data for the two Polyot missions as given by the Royal Aircraft Establishment Tables [3], and their additional information allows some delta-V calculations to be made. Fig. 1 shows the geometry of the Polyot manoeuvres since they were not made at a nodal crossing. The Polyot 2 launch announcement suggested that the orbital plane change was made near the equator, but in fact it seems that the burn was made near the apogee point at about 47°S. Table 2 shows the values obtained during the calculation of the delta-Vs, following the abbreviations used in Fig. 1 The RAE quotes no initial orbital inclination for Polyot 1, and for this I have *assumed* that the payload had the same inclination as the initial Polyot 2 orbit. It will be noted that the Polyot 1 in-orbit manoeuvre was 383 m/s and that for Polyot 2 was 480 m/s. It is possible that the two craft were identical and the difference of about 100 m/s delta-V was made up in the launch phase of the vehicles.

There is one confusing point in the RAE's entry for Polyot 2. The launch announcement suggests that Polyot 2 only put itself into orbit, since all the launch vehicle stages were sub-orbital: however, the RAE shows an object designated a "Rocket" (1964-19A) which decayed from orbit after 18½ days. Since it decayed so quickly from what was a reasonably high orbit (236-465 km), this might simply be a small fragment thrown off by Polyot 2 soon after orbital injection.

Polyot 1 seems to have manoeuvred quickly from its initial orbit, while reference to the epochs of the RAE orbits in Table 1 shows that Polyot 2 remained in its initial orbit for a

Table 1. Polyot Orbital Data.

Epoch	Incl* deg	Period min	a* km	e*	Perigee km	Apogee km	AoP* deg
		(a) Polyot 1, launched 1963 Nov 1.37					
Nov 1.4	(59.92)**	94.0	6843	0.018	339	592	—
Nov 2.0	58.92	102.46	7268	0.075	343	1437	114
		(b) Polyot 2, launched 1964 Apr 12.39					
Apr 14.1	59.92	91.86	6742	0.018	242	485	57
May 10.8	58.06	92.31	6769	0.013	303	479	98

Extracted from Ref 3, pages 41 (Polyot 1) and 50 (Polyot 2).

*Incl=orbital inclination; a=semi-major axis of orbit; e=orbital eccentricity; Aop=argument of perigee.

**Not available from "open" sources: estimated by the author.

Table 2. Polyot Orbital Manoeuvres.

Symbol*	Polyot 1	Polyot 2
x_0	115°	60°
i_0	58.92°	58.06°
i_1	59.92°	59.92°
L	50.91°	47.30°
z_0	132.09°	42.50°
a_0	54.97°	51.27°
x_1	116.24°	58.13°
z_1	134.52°	38.87°
a_1	52.65°	47.64°
0	2.32°	3.63°
V_0	7774.3 m/s	7552.0 m/s
V_1	7985.6 m/s	7574.6 m/s
dV	382.7 m/s	479.6 m/s

*See notes for Fig 1.

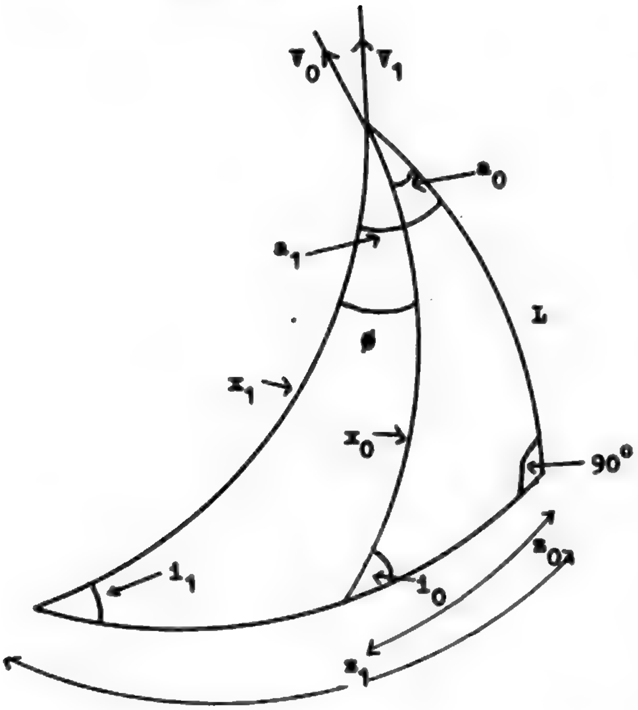

Fig. 1. Geometry of Polyot Manoeuvres. The arc x_0 is part of the original orbit with an inclination i_0 degrees, with a velocity V_0. L is the latitude at which the orbital change is made. The items x_1, i_1 and V_1 are similarly defined for the subsequent orbit. The angle $Ø(a_1-a_0)$ is the angle through which the spacecraft moved during the orbital burn. The arcs z_0 and z_1 and angles a_0 and a_1 can be found from standard spherical trigonometric equations, and the delta-V is calculated by applying the law of cosines to the vector triangle with two sides V_0 and V_1 and included angle Ø.

day or two after launch, the manoeuvres not coming until after early 14 April 1964.

Possible Missions for Polyot

It was expected that there would be a series of Polyot flights, followed by an easily-identifiable operational use of the manoeuvring system. However, the flights ended after the second launch, and it is difficult to point with certainty at the operational use of the technology. The launch of Polyot 2 on Cosmonautics Day (the anniversary of Yuri Gagarin's flight) suggests that there might be something special about the craft.

The launches came from Tyuratam, and the inclination used had not been used before and has not been used since. The closest inclination to 59.9° to be employed is 61°, used for the twin Elektron flights in 1964. The Elektron flights used the Standard Launch Vehicle, the "A-1" in Sheldon's system of designations. Sheldon (Ref 4, 557) lists the Polyot launch vehicle as "A-m", that is the basic SS-6/Sapwood booster without any upper stages: "m" refers to the manoeuvrable Polyot craft.

Considering the programmes being undertaken at the time, there are perhaps four missions which might be considered for the application of the Polyot experience:

(1) Testing the "e-stage" of the "A-2-e" deep space launch vehicle.

(2) Testing an up-rated Vostok instrument module for possible use in the Voskhod programme.

(3) Testing the second generation Luna instrument module.

(4) Initial test flights of the Soyuz manoeuvring system.

These four ideas are more fully developed below.

An "e-Stage" Test?

It should be remembered that in the early 1960s the small escape stage added to the up-rated Vostok launch vehicle ("A-2") had proved very unreliable. In 1962 three Venus probes and two Mars probes were stranded in Earth parking orbits due to the failure of the "e-stage" to work properly. Out of six planetary shots, only Mars 1 got onto a heliocentric orbit. At the beginning of 1963 the first of the second generation Luna probes was left in Earth orbit after a similar failure. Following the problems with Luna 4 in April 1963, the Soviets could have decided to halt flights of the "A-2-e" launch vehicle until the "bugs" had been sorted out of the fourth stage. In 1964 there were launch windows for both Venus (March-April) and Mars (November) and the Soviets wanted to launch probes if at all possible.

The RAE suggests that the Polyot craft was irregular, about 2 metres long and 1 metre in diameter: the mass is estimated to be about 600 kg. Full data is not available for the "e-stage", but it seems to be generally 2.5 metres long and 2 metres in diameter, with a mass of around 1000 kg (Ref 5, 331). This is not too far from the Polyot estimates.

The fuelled mass of the "e-stage" is about 6¼ tonnes (Venera 8 was 1184 kg, and the fuelled parking orbit mass was about 7500 kg), so it could not be launched fully fuelled into orbit by the Sapwood booster without an upper stage. The maximum payload orbited by the Sapwood alone was Sputnik 3 into a 65.2°, 220/1865 km orbit. The Sputnik had a mass of 1327 kg, which would scale with about 2600 kg to the initial Polyot 1 orbit. If the fully fuelled "e-stage" had been launched atop the Sapwood the launch delta-V obtained would have been in excess of 12 km/s, so if the "e-stage" had been flown it could not have been fully fuelled. However, one of the problems with the "e-stage" was that it was only completing partial burns, if it ignited at all, so a test of a partially fuelled version would simply have proved that the stage's engine would ignite, not that it would burn to depletion.

There is one other piece of evidence which would seem to rule out the use of the "e-stage" on a Sapwood. Polyot had a restart capability, as shown by its ability to enter an initial orbit and then about two days later manoeuvre to another orbit. The "e-stage" has never exhibited a re-start capacity and this would not be required on any of its missions which only need a single burn to be accomplished.

An up-rated Vostok Engine System?

When the modified Vostok was introduced into the manned programme as the Voskhod in October 1964, it was expected that the craft would have an orbital manoeuvre capacity which would allow later Voskhods to complete a rendezvous and docking. The Vostok instrument module had a fuelled mass of about 2050 kg. The specific impulse of the TDU-1 engine was 266 sec and according to Vick (Ref 6, 299) this implied a fuel capacity of 155 kg.

The Vostok had a mass of about 4750 kg while Voskhod 2 had a mass of nearly 5700 kg. A possible rendezvous version of Voskhod might have had a mass of about 6,000 kg. A possible mass breakdown of such a vehicle is suggested in Table 3. An extra 100 m/s of manoeuvring fuel has been allowed for the rendezvous mission.

If Polyot was a test of the up-rated Vostok instrument unit for a Voskhod rendezvous mission, the new unit launched alone would have a delta-V capacity of 480 m/s which ties in very well with the Polyot 2 manoeuvres, so this is a possible contender. Unfortunately, if any Voskhod flights were planned

Table 3. Possible Vostok and Voskhod Mass Breakdowns.

Mission	Vostok 2 kg	Voskhod 2 kg	Rendezvous Voskhod kg
Spare retro unit	—	465	500
Cabin	2,500	2,800	2,855
Instrument Module	2,075	2,200	2,200
Fuel	155	215	445
	—	—	—
Total Mass	4,730	5,680	6,000
Delta-V capacity	87 m/s	100 m/s	200 m/s

Note. It is assumed that Voskhod used the same TDU-1 instrument unit engine as did the Vostok craft. The spare retrorocket unit was carried on top of the Voskhod sphere.

after the second manned flight, they did not appear, so we cannot say what kind of manoeuvres such a mission would require.

A Luna Instrument Module Test?

Luna 4 was launched in April 1963 to the Moon, but it seems to have failed to make even the most minor of mid-course corrections, thus pointing to a possible failure of the KDTU-1 manoeuvring unit. It has been noted previously by the writer that the second generation Luna instrument/retro-fire stage had an empty mass of about 370 kg and carried up to 830 kg of fuel[7]. If the unit were to be launched without the Luna capsule and navigation system it would have a delta-V capacity of 3200 m/s, which is far too high for a Polyot mission. Perhaps the unit was only partially fuelled. Even so, the mass would be too little for the Sapwood to place in the orbits which we have seen. Therefore, Polyot does not seem to be connected with the problems in the Luna programme.

A Soyuz Manoeuvring System Test?

Most observers of the Soviet space programme generally agree that the Voskhod programme conducted in 1964-5 (with the Voskhod named Cosmos 110 carrying two dogs in 1966) was no more than a stop-gap measure between the Vostok and impending Soyuz manned programmes. If Voskhod had not intervened it seems probable that Soyuz would have flown its initial manned missions in 1965, after unmanned test flights in 1964 and early 1965. If this timetable is near the truth, the initial testing of the Soyuz manoeuvring system would be expected after completion of the Vostok missions in 1963 and before the first fully-fledged unmanned Soyuz missions in 1964. This timing agrees with the launch dates of the Polyot craft.

It has been noted by Woods [Ref 8, 283-5] that Soyuz has had two propulsion systems. The first used a torus fuel tank, with additional fuel being carried in four spheres in the Soyuz instrument module. One has to ask which (if either) of these two systems would best fit the Polyot missions.

The Soyuz instrument module (using Woods' Table 9 in the last reference) has an empty mass of 1860 kg, including the torus fuel tank, while 2965 kg of fuel (1150 kg in the spheres and 1815 kg in the torus) can be carried. The re-entry module for Soyuz/Zond is estimated to be about 2600 kg, although on a possible early propulsion test only a boiler-plate module need be carried, since a re-entry was not to be attempted. Taking the instrument module as 4,825 kg, a payload shroud directly over the top of the Sapwood of 3,500 kg (for Soyuz this seems to be 4,500 kg), and a boilerplate re-entry module of 1,750 kg, results in a delta-V of about 8400 m/s from launch to final orbital change, which is that found on Polyot 2. For Polyot 1 the launch delta-V was about 8300 m/s. Therefore, the figures

Table 4. Cosmos 102 and Cosmos 125 Orbital Data.

Epoch	Incl deg	Period min	a km	e	Perigee km	Apogee km	AoP deg
		(a) Cosmos 102, launched 1965 Dec 27.93					
Dec 28.7	64.97	89.20	6614	0.005	203	269	241
		(b) Cosmos 125, launched 1966 Jul 20.38					
Jul 21.2	65.00	89.12	6610	0.004	205	258	277

Extracted from Ref 3, pages 97 (Cosmos 102) and 113 (Cosmos 125).

would seem to fit the hypothesis that the Polyots were early Soyuz tests.

Cosmos 102 & 125: A Connection?

At the end of 1965 and in mid-1966 there were two flights in the Cosmos programme which are sometimes connected with the two Polyot flights: Cosmos 102 and Cosmos 125 [4, 52]. The orbital data for the two flights, as extracted from the RAE Tables, is given in Table 4. The RAE describes the payloads (there were no separate carrier rockets in orbit) as possibly being 10 m long (?) and 2 m in diameter (?): Cosmos 102 is described as being cylindrical, while Cosmos 125 is described as a cone-cylinder, with a mass of 4,000 kg (?).

The speculation about a Polyot connection with these flights stems from the two Cosmos orbits having perigees far in the southern hemisphere, as if an engine had ignited on its first pass through a southern hemisphere apogee to boost the former perigee to a new apogee. However, nowhere is there an indication of an orbit earlier than the one shown for each mission, so it is impossible to indicate the amount of the orbital burn.

Sheldon lists the two Cosmos flights as using the Sapwood in an "A-1-m" version; that is the standard Vostok booster with an unknown manoeuvring unit added. Whether this "m" stage is the same as that found on the Polyot "A-m" flights cannot be decided finally, although the present writer tends to think not. The implied orbital changes for the Cosmos missions are too small for a Polyot application, and the missions might be connected somehow with the development of hardware to be subsequently used by the military Scarp launch vehicle.

Conclusion: Voskhod or Soyuz/Zond?

Of the original four ideas for the application of Polyot technology, the only ones to have stood the test of analysis are the hypothetical Voskhod manoeuvring system and an early development version of the Soyuz vehicle. Faced with these two contenders the writer would certainly choose the latter. There is no proof that Voskhod was being readied for a rendezvous version, and with the spare retrorocket system being on top of the Voskhod sharik, the geometry of an actual docking is difficult to visualise. Soviet plans for a docking after the Voskhod 2 flight most probably hinged on the new Soyuz being available for manned flight before the end of 1966.

In addition, it should be noted that, although the delta-V of Polyot is a close match for that on the hypothetical Voskhod unit, it *only just* fits. There is no lee-way to allow for Polyot placing itself in orbit, and we would require only the instrument unit to be launched: no Voskhod sharik, otherwise the payload could not even perform the known Polyot manoeuvres.

It seems probable that, although the main Soyuz programes was delayed due to the hastily-prepared Voskhod missions, some early Soyuz hardware would be in the pipe-line for flight testing in late 1963, if all-up unmanned flights were to take place in the latter half of 1964 (such flights would be like Cosmos 133 and 140 in late 1966 and early 1967 respectively).

Having said all this, it seems most unlikely that we shall ever know for certain what the application of the Polyot

manoeuvring system was, unless we have a radical change in the Soviet Union's information policy.

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ANIMAL PRECURSORS TO MANNED SPACE FLIGHT

By Joel Powell

Introduction

What was it like to travel in outer space? What were the effects of space travel on living organisms? These were the questions that concerned early space scientists after the Second World War when they realised that the development of large war rockets put the age-old dream of space travel within reach.

When the captured German V-2 rockets were earmarked by the American government for upper-atmospheric research, Dr. James P. Henry (USAF) of the Aero Medical Laboratory seized upon the opportunity to plan animal experiments to fly "piggy-back" on the rockets. [1] He obtained approval for the "Albert" project and enlisted the aid of a number of like-minded Air Force scientists, among them Lt. Col. David Simons, later to gain fame in the "Man High" balloon flights. [2] They fought for every scrap of support they could get, convinced that the "way to the stars" [3] was with the use of animal experiments in space.

Monkeys and Mice

The group chose the rhesus monkey as the subject [3] and went about designing a life support capsule for it. Due to its hitch-hiker status, the life cell was severely restricted in its weight and volume. [5] This first space cabin was an aluminium structure approximately three feet long and fifteen inches in diameter. A parachute recovery system was provided.

Four flights were made between June 1948 and December 1949. Unfortunately the flights were less than successful; three of the monkeys died at the rocket's impact and another shortly after launch (see table). Data from the animals revealed that acceleration levels were within tolerable limits, 5.5. g's on ascent and 12–13 g's on descent and there was "no evidence of any ill-effect to the monkeys as a result of rocket flight conditions" [6].

To study zero-gravity effects not investigated previously, an unanesthetised mouse was launched aboard a V-2 in August 1950. A camera was carried to photograph the mouse in free-fall which showed that the creature "retained normal muscular coordination throughout subgravity" [7]. Prior to these experiments, it was felt that space flight conditions would force a man to lose physical perspective and would directly affect mental ability and coordination required to perform physical tasks [8]. The V-2 results indicated that this may not be so and encouraged the scientists to plan further flights.

The next step was three animal flights using Aerobee sounding rockets. A tailor-made life support and recovery system was designed for the macaque monkey and mice subjects [9]. Instruments on the single monkey launched in April 1951 showed that weightlessness apparently did not affect the animal [10]. In September 1951 a monkey and eleven mice were recovered for the first time from a rocket flight. The monkey and mice experienced no unusual effects from weightlessness or up to 17 g of acceleration. Nine of the mice showed "no significant after-effects" [11] from exposure to cosmic rays. In both the September 1951 and May 1952 flights, two mice were

Monkeynaut "Baker," which made a sub-orbital flight in a Jupiter nosecone in May 1959, survives to this day at the Alabama Space and Rocket Center, Huntsville.

ASRC

photographed in a transparent circular cage to gauge their reactions to weightlessness. By using tactile touch senses and by clinging to paddle-like supports the mice remained fairly quiet after an initial period of thrashing about aimlessly [12,13]. There was no evidence that weightlessness affected any of the animals' heart rates, blood pressure or respiratory systems [14].

Despite "severe criticism" [15] from animal lovers from around the world which brought about the suspension of animal flights, lasting until 1958, scientists felt they had enough data to conclude that a man could probably survive a flight into space. However much work remained to be done.

Soviet Space Dogs

In the Soviet Union, Russian space scientists took a slightly different approach to the problem than did the Americans. So-called "geophysical rockets" based upon the design of the V-2 and Sandal SS-4 military missiles were used to launch heavy, sophisticated biological payloads from Kapustin Yar [16] near the Caspian Sea. In the tradition of Pavlov, mongrel dogs were used as primary subjects.

Table 1. List of all American and Soviet animal-carrying Rocket Flights 1948-61

Date	Rocket designation	Notes and launch site
June 18, 1948	V-2	Albert I killed; White Sands
June 14, 1949	V-2	Albert II killed, rocket failure; White Sands [1]
Sept. 16, 1949	V-2	Albert III killed; White Sands [2]
Dec. 8, 1949	V-2	last monkey Albert IV killed; White Sands [3]
Aug. 31, 1950	V-2	unanethzetized mouse killed on impact; White Sands [2]
Apr. 18, 1951	Aerobee	one monkey carried, killed on impact; Holloman AFB [4]
Sept. 20, 1951	Aerobee	monkey and 11 mice carried, recovered; Holloman AFB [5]
May 21, 1952	Aerobee	2 monkeys, "Pat", "Mike', 2 mice carried, recovered; Holloman AFB [6]
May 26, 1955	A-4	USSR flight with 2 dogs; Kapustin Yar [7,8]
June 1, 1956	A-4	USSR flight with 2 dogs; Kapustin Yar [7]
June 7, 1956	A-4	USSR flight with 2 dogs; Kapustin Yar [7]
June 14, 1956	A-4	USSR flight with 2 dogs; Kapustin Yar [7]
June 22, 1956	A-4	USSR flight with 2 dogs; Kapustin Yar [7]
July 20, 1956	A-4	USSR flight with 2 dogs; Kapustin Yar [7]
Dec. 20, 1956	A-4	USSR flight with 2 dogs; Kapustin Yar [7]
May 16, 1957	A-4	USSR flight with 2 dogs; Kapustin Yar [7]
Apr. 23, 1958	Thor-Able "Re-entry 1"	mouse "MIA-1" lost, rocket "destructed"; Cape Canaveral [9]
July 9, 1958	Thor-Able "Re-entry 2"	mouse . "MIA-2" lost at sea; Cape Canaveral [9]
July 23, 1958	Thor-Able "Re-entry 3"	mouse "Wilkie" lost at sea; Cape Ganaveral [9]
Aug. 27, 1958	A-3	2 dogs reportedly perished in USSR flight; Kapustin Yar [7,10]
Sept. 19, 1958	A-3	USSR flight with 2 dogs; Kapustin Yar [7]
Oct. 31, 1958	A-3	USSR flight with 2 dogs; Kapustin Yar [7]
Dec. 12, 1958	Jupiter	squirrel monkey "Old Reliable" lost at sea; Cape Canaveral [9]
Dec. 23, 1958	A-3	USSR flight with 2 dogs; Kapustin Yar [7]
May 28, 1959	Jupiter	monkeys "Able" and "Baker" and bio-payload recovered; Cape Canaveral [11]
July 2, 1959	A-2	USSR flight with 2 dogs and one rabbit; Kapustin Yar [7,12]
July 10, 1959	A-2	USSR flight with 2 dogs; Kapustin Yar [7]
July 14, 1959	A-2	USSR flight with 2 dogs; Kapustin Yar [7]
Sept. 16, 1959	Jupiter	14 mice and bio-payload lost when rocket "destructed"; Cape Canaveral [9]
Dec. 4, 1959	Little Joe LJ-2	monkey "Sam" recovered in Mercury capsule; Wallops Island [9]
Jan. 31, 1960	Little Joe LJ-1B	monkey "Miss Sam" recovered in Mercury capsule; Wallops Island [9]
June 15, 1960	A-2	USSR flight with 2 dogs and one rabbit; Kapustin Yar [7]
June 24, 1960	A-2	USSR flight with 2 dogs; Kapustin Yar [7]
Sept. 16, 1960	A-2	USSR flight with 2 dogs; Kapustin Yar [7]
Sept. 22, 1960	A-2	USSR flight with 2 dogs; Kapustin Yar [7]
Oct. 13, 1960	Atlas D	RVX-2A nosecone recovered with mice "Amy", "Sally", "Moe"; Cape Canaveral [9]
Jan. 31, 1961	Redstone MR-2	Mercury capsule recovered with chimpanzee "Ham"; Cape Canaveral [9]
Nov. 10, 1961	Atlas E "Spurt"	Small Primate Unrestrained Test [13] monkey "Goliath" killed when rocket "destructed"; Cape Canaveral [9]
Dec. 20, 1961	Atlas F	Rhesus monkey "Scatback" lost at sea; Cape Canaveral [9]

Note: The Soviets stated that they launched six rockets with a total of nine dogs in 1951-52 and an additional flight in 1955 with two dogs per flight but did not disclose the exact dates. They launched a total of 25 animal-carrying flights [14]. Several of the dogs flew more than once.

The initial series of animal experiments (see table) were made using A-1 rockets which took a total of six dogs to about 100 km. altitude [17]. In flights conducted during 1952-56, larger rockets were used to reach altitudes of 100-110 km [18]. In these flights the animals were placed in three-ply rubberized pressure garments with plexiglass helmets. One unpressurized dog capsule was ejected at an altitute of 75-90 km. and the other at 35-50 km., with recovery by parachute [19].

The 1957-60 flights involved heavy payloads lofted to altitudes of 212 to 450 km [20] with two dogs in sealed cabins of 0.46 m3 volume [21]. The dogs were filmed in flight and arterial pressure, pulse, respiration, skin and body temperatures were measured [22].

Total flight time was from 600-660 seconds with up to 370 seconds of weightlessness. "Although changes were noticed in blood pressure and respiration during periods of high g-loading, no departure from normal was witnessed in the weightlessness phase of the flight [23]," according to Soviet researchers. Heart rates increased in all dogs during active flight and returned to normal after landing. The Soviets noted that unfettered dogs became "extremely uncontrolled and uncoordinated as soon as they were weightless" [24], but they were able to recover and react to the situation. Soviet scientists were able to conclude that rocket flight into space should pose no serious limitations to man.

After satellites and spaceflight became a reality in 1957, scientists had more motivation than ever to investigate space travel conditions. Both the Americans and Soviets formulated plans to put a man into space prompted by the success of Sputnik. Space biology programmes in both countries were pursued with renewed vigour.

The first American biological investigation since 1952 was the MIA (Mouse in Able) project headed by Miss Franki van der Wal and W. D. Young of Space Technology Laboratories [25]. They flew mice on three Thor-Able re-entry research rockets to gather data on the effects of weightlessness. The

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mice rode separable recovery capsules, but unfortunately none were recovered. One mouse, "MIA-2" or "Laska", survived 60 g acceleration and 45 minutes weightlessness before perishing. The only note-worthy physical effect was an increase in heart rate at the onset of zero-gravity. One of the mice reached an altitude of 1,400 miles, then a record [26].

On 12 December, 1958 a Jupiter missile was launched from Cape Canaveral carrying a one pound squirrel monkey named "Old Reliable" [27] in a specially designed recoverable capsule. Although the monkey was not recovered, it provided the most significant biomedical results of the early space programme. The physical monitoring sensors showed that "Reliable's" pulse rate increased during the acceleration of liftoff but not as much as anticipated. When weightlessness began respiration returned to normal and the pulse rate levelled off within 45 seconds [28]. "This is amazing," kept exclaiming the doctor.

The monkey experienced no ill-effects whatsoever in the 8.3 minutes [29] of weightlessness. Navy Capt. Norman Barr M.D., chief scientist, wrote, "This is of immense significance to man. With a single exception, "Reliable" was experiencing the same physical conditions a man will one day know in space, and we have every reason to believe man's reactions will be essentially the same" [30].

Able and Baker

Buoyed by the success of "Old Reliable", space scientists then conducted the most elaborate space life science investigation of the suborbital series. On 28, May 1959 another Jupiter missile was fired from Cape Canaveral carrying a squirrel monkey, a spider monkey and a menagerie of living specimens. For the first time the Americans safely recovered the capsule and its passengers and for the first time outside the Soviet Union scientists were able to study the effects of space flight on the cellular structure and genetic material of specimens that had flown in space. The two monkeys, "Able" and "Baker", survived the trip without harm. Unfortunately monkey "Able" died a few days later on the operating table during the removal of a biomedical electrode. Her companion "Baker" lives to this day at the Alabama Space and Rocket Centre, Huntsville, Alabama [31].

Monkey "Able" was trained to tap a switch looking like a telegraph key every time a red light flashed in her compartment. The experiment was not successful but it represented the first attempt to obtain actual animal performance data during space flight [32]. This investigation would be a major part of future animal flights [33].

The next three flights with monkeys heavily emphasized performance testing. On 4, December 1959 the monkey "Sam" flew in a Mercury test spacecraft to gather information on the effects of acceleration in rocket flight. "Sam" was trained to press a lever when a red light came on or suffer an electric shock [34]. "Sam" did well at first but later did not respond to the cue to press the lever as often as desired. This may have been due to the acceleration stresses of the moment [35]. The aim of the tests was to determine the amount of voluntary muscle control a man might have in a space flight [36].

On 21, January 1960, "Miss Sam" repeated "Sam's" Mercury spaceflight and also conducted the performance test. She did not do as well as "Sam", but returned to work more quickly after the escape rocket mechanism fired. "Her performance record of the last 8.6 minutes was of a high level and indicated that "Miss Sam" suffered no persistent physiologic deterioration as a result of the flight," wrote Bergwin and Coleman.

Astrochimp "Ham", who now lives at the Washington D.C., National Zoo, flew in a Mercury spacecraft on a full-scale rehearsal of Alan Shepard's suborbital flight on 31 January 1961. "Ham" performed a more sophisticated test using a panel with two levers and three lights. He was to push lever two when the red light was on and to push lever one when the blue light was on. A white light flashed signifying a correct response and an electric shock signalled an error [38]. His rate of response fell off slightly during the strenuous re-entry but on the whole was very satisfactory. These tests showed that man could be expected to perform tasks normally from launch to re-entry during a space voyage [39].

An investigation to detect possible harmful efforts of space radiation on genetics was conducted with three mice who flew in an Atlas nose cone on 13, October 1960. Two of the mice were mated so that their offspring could be studied to detect any radiation-induced mutations. The mouselings produced by "Amy" and "Moe" happily did not show "any genetic traces of their parent's space voyage" [40]. The negative result was taken as particularly significant because "Amy", "Sally" and "Moe" withstood the longest period of weightlessness in a suborbital flight, 20 minutes [41].

Thanks to the trailblazing animals that preceded him, man was able to go into space fully appraised of the conditions that awaited him. Through these pioneers it was learned that acceleration and weightlessness were not the debilitating factors that they once were believed to be. The way was clear for man to make his first short ventures into outer space.

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SATELLITE DIGEST–140

A monthly listing of all known artificial satellites and spacecraft. A detailed description of the information presented can be found in the January 1979 issue, p. 41.

Compiled by Robert D. Christy

Continued from July-August issue

Name, designation and object number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch site launch vehicle and payload/launch origin
Cosmos 1167 1980-21A 11729	1980 Mar 14.44 6 months?	Cylinder?	6 long? 2 dia	142 428	595 444	65.01 65.03	91.92 93.31	Tyuratam F-1-m USSR/USSR (1)
Cosmos 1168 1980-22A 11735	1980 Mar 17.90 1000 years	Cylinder 700?	2 long? 2 dia?	962	1013	82.95	104.90	Plesetsk C-1 USSR/USSR (2)
Cosmos 1169 1980-23A 11741	1980 Mar 27.31 2 years	Cylinder?	4 long? 2 dia?	476	515	65.84	94.52	Plesetsk C-1 USSR/USSR (3)
Progress 8 1980-24A 11743	1980 Mar 27.786 29 days 1980 Apr 26.3	Sphere+cone-cylinder 7000	8.0 long 2.2 dia	180 300 338	260 320 354	51.6 51.6 51.62	88.8 90.6 91.39	Tyuratam A-2 USSR/USSR (4)
Cosmos 1170 1980-25A 11747	1980 Apr 1.33 11 days (R) 1980 Apr 12.2	Cylinder+sphere+cylinder-cone? 6000?	6 long? 2.4 dia?	170 166 166	371 331 345	70.39 70.34 70.36	89.95 89.50 89.65	Tyuratam A-2 USSR/USSR (5)
Cosmos 1171 1980-26A 11750	1980 Apr 3.32 1000 years	Cylinder	4 long? 2 dia?	965	1009	65.84	104.87	Plesetsk C-1 USSR/USSR (6)
Soyuz 35 1980-27A 11753	1980 Apr 9.568	Sphere+cylinder-cone 6500?	7.5 long 2.2 dia	193 272 336	243 315 346	51.62 51.62 51.62	88.80 90.32 91.29	Tyuratam A-2 USSR/USSR (7)
Cosmos 1172 1980-28A 11758	1980 Apr 12.85 12 years?	Cylinder-cone+6 panels+antennae? 1000?	3.4 long? 1.6 dia?	609 617	40146 39821	62.76 62.80	725.91 719.46	Plesetsk A-2-e USSR/USSR (8)
Cosmos 1173 1980-29A 11763	1980 Apr 17.36 11 days (R) 1980 Apr 28	Cylinder+sphere+cylinder-cone? 6000?	6 long? 2.4 dia?	176 155	355 355	70.31 70.31	89.78 89.64	Tyuratam A-2 USSR/USSR (9)
Cosmos 1174 1980-30A 11765	1980 Apr 18.03	Cylinder?	4 long? 2 dia?	362 380	1025 1660	65.84 66.12	98.65 105.55	Tyuratam F-1-m USSR/USSR (10)
Cosmos 1175 1980-31A 11767	1980 Apr 18.73 3 months	Cylinder-cone+6 panels+antennae? 1500?	4.2 long? 1.6 dia?	252	459	62.84	91.66	Plesetsk A-2-e USSR/USSR (11)

Supplementary notes:

(1) Possibly an ocean survey type reconnaissance satellite. Previous flights of this type of vehicle were Cosmos 1094 (1979-33A) and Cosmos 1096 (1979-36A). Orbital data are at 1980 Mar 14.5 and Mar 14.7.
(2) Probably a navigation satellite.
(3) Interception test radar calibration target. See note 6 below.
(4) Unmanned supply vehicle carrying replacement parts and materials to Salyut 6 prior to the Soyuz 35 visit. The first two orbits are based on estimated data and are at 1980 Mar 27 and 1980 Mar 28. The third orbit, after docking at 1980 Mar 29.8, is at 1980 Apr 7.8. This orbit was achieved by an upward manoeuvre of the Salyut/Progress complex on 1980 Apr 3, using the Progress 8 engine.
(5) Orbital data are at 1980 Apr 1.7, Apr 2.1 and Apr 6.1.
(6) Target for Cosmos 1174 satellite interception test.
(7) Ferry vehicle which carried Leonid Popov and Valery Ryumin to Salyut 6. Launched at 1338 UT on Apr 9, docking took place at 1516 UT on Apr 10. Orbital data are at 1980 Apr 9.8, Apr 10.3 and Apr 13.2.
(8) Cosmos 1172 may be an early warning satellite. Orbital data are at 1980 Apr 13.9 and Apr 18.9.
(9) Orbital data are at 1980 Apr 17.5 and Apr 18.1.
(10) Satellite interception test using Cosmos 1171 as its primary target. Orbital data are at 1980 Apr 18.1 and Apr 18.6.
(11) Probably a failed Molniya-3 satellite.

Amendments

1980-13A, Cosmos 1164 was more probably a failed early warning satellite than a Molniya-1.

1980-20A, Cosmos 1166 was recovered 1980 Mar 18, lifetime 14 days.

SOVIET SETI STUDIES

By Boris Belitsky

Introduction

The debate in the Soviet scientific community over the problems of SETI (the search for extraterrestrial intelligence), reported in an earlier issue of *Spaceflight* [1], has predictably in no way blunted interest in these problems. Although the views of the eminent radio astronomer Dr. Iosif Shklovsky – who has challenged the very notion of the multiplicity of inhabited worlds, at any rate in our metagalaxy [2] – are respected by his colleagues, quite a few of whom are also his pupils, they are not in any way seen as constraints upon either practical research or theoretical discussion in the SETI field. Indeed, I would hesitate to name a single Soviet SETI researcher who has been converted to Shklovsky's thinking on the subject.

SETI Section

Over the past months I have regularly attended the meetings of the SETI Section, a permanent group under the Radio Astronomy Council of the USSR Academy of Sciences. The chairman of the Section is Dr. Vsevolod Troitsky, the pioneer of practical SETI studies in the Soviet Union. Since, however, he is based in Gorky, where he is a deputy director of the Academy's Institute of Radiophysics, the meetings are sometimes convened and chaired by the enthusiastic and imaginative secretary of the Section Dr. Lev Gindilis. Invariably they provide a venue for bold and wide-ranging debate on the whole area of SETI research and problems.

Spaceborne Radio Telescopes

In a presentation at a meeting of the Section in January 1980, Dr. Nikolai Kardashev, a deputy director of the Academy's Institute of Space Research, defended his SETI strategy. Described at some length in an earlier article [3], this unconventional strategy concentrates on searching for "supercivilizations," far more advanced than our own civilization and commanding far more powerful transmitters.

Such a strategy calls for a two-pronged search. On the one hand, it requires searching for evidence of astro-engineering activity, which should be detectable even over cosmic distances either through its thermal (black body) radiation, the screening effect of such structures, their reflection of the background radiation in various parts of the spectrum. On the other hand, Kardashev's strategy acknowledges the need to search for communication signals from "suspect" sources. The optimal frequency range of such signals should be determined, he believes, by taking into account the background radiation in the vicinity of the source and the conditions of signal propagation in the cosmic plasma. Particularly promising, in his view, is the millimetre range because of the background radiation peak there. He hopes that such an effort will either tie known astronomical objects to intelligent activity or lead to the discovery of an entirely new class of such sources.

The strategy relies upon big radio telescopes operating in a wide frequency range. Indeed, it can only hope to succeed by linking such telescopes for Very Long Baseline Interferometry. Since international cooperation has already made possible experiments in which the baseline has been of a length close to the diameter of the Earth, the next logical step is clearly to use spaceborne radio telescopes for such experiments.

At the time of the previous report on this subject [4], the Soviet spaceborne radio-telescope project had not yet got off the ground. But since then the success of the KRT-10 radio telescope experiment aboard the Salyut-6 orbital station has given the project a new, practical dimension. Since this experiment has already been described to *Spaceflight* readers [3], let it merely be added here that its success makes it certain the KRT-10 was but the first of a progression of such instruments of increasing size and sophistication to be used for astrophysical studies generally and SETI in particular. Ultimately, such a progression could lead to the "Infinitely Built-Up Space Radio Telescope", described in previous issues [4, 5]. Such a giant space telescope of up to 10 km diameter, assembled from 200-metre modules, could search the wavebands very effectively for evidence of extraterrestrial intelligence. Moreover, fruitful observations could begin with the assembly of a spherical antenna of 3-km diameter. The possibility of obtaining three-dimensional, holographic pictures of remote objects in space would make this a truly revolutionary new instrument of SETI.

All-Sky Survey

Whereas the Kardashev strategy requires studying the most powerful (often very remote) sources in the Universe first and passing on to fainter ones only when the signals from the more powerful sources have been proved to be of natural origin, Troitsky, favours a more conventional strategy. A SETI veteran, he reported the results of an OZMA-like search project

to the CETI international conference at Byurakan, in Soviet Armenia, in 1971. The all-sky survey he and his colleagues have been conducting since then – for ten years now – has been all-embracing, which has been achieved, to some extent, at the expense of sensitivity. He now maintains that the negative result of this search rules out the existence of any "supercivilizations," such as are postulated by Kardashev, and he sees the negative results of similar American search projects as corroborating this conclusion.

Troitsky's New Theory

At the meeting of the Section in January, Troitsky proposed a new theory to account for the absence of such "supercivilizations". It is necessary, he maintains, to give up the traditional assumption that life arises in the Universe continually, with the formation of planets capable of supporting life. This need not be so. Life could have arisen only once – at a definite moment in the evolution of the Universe as a whole. At that moment it could have arisen simultaneously in many parts of the Universe – wherever chemical conditions in the process of the evolution of matter had become suitable. Since then life has never arisen again, but has been undergoing evolution – from simple life-forms to the more complex, such as intelligent life. The rate of this process on our own planet is well-known: our technological civilization is the result of approximately 4,000 million years of evolution.

If this is higher than the evolution rate in the other places where life arose 4,000 million years ago, we are the most advanced civilization. On the other hand, conditions elsewhere could have been more favourable, and other civilizations may be somewhat more advanced than ours, but not advanced enough to be sending out powerful signals over cosmic distances. Moreover, in Troitsky's opinion, signals of such power would be harmful to a civilization's environment . . .

Troitsky believes that his conception of the origin of life in the Universe as a one-time event is more in keeping with the observational data than is Kardashev's. Like debates in any other area of science, theirs, in the view of Soviet scientists, can be resolved only by the accumulation of research data. In this respect, as Troitsky remarks, the search for extraterrestrial intelligence scarcely differs from the search for quarks, neutron stars, or gravitational waves, all of which have been postulated theoretically, but have yet to be confirmed by "hard" evidence.

Broadening Approach

In general, Soviet SETI research and the whole field of astrophysics have lately been marked by a growing broadmindedness. For example, the nuclear physicist Dr. Moisey Markov interprets the general theory of relativity as permitting the existence of systems that, to an external observer, would appear as elementary particles, whereas to an internal observer they would appear as universes, with myriads of galaxies, stars, planets, and – civilizations! Kardashev regards electrically charged black holes as opening up entirely new dimensions of space and time for travel. And Gindilis is engaged in a study of anomalous atmospheric phenomena.

All this may cause a lifted eyebrow here or there in more traditionally-minded scientific quarters, but is indicative of the new and highly promising "no holds barred" approach to some of the most baffling scientific problems of our times . . .

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SPACE REPORT

A regular monthly review of Space Events and Technical Trends

Ariane 02 blasts off from Kourou, French Guiana, on 23 May 1980.

ESA

ARIANE HITS A SNAG

On 23 May the second Ariane launch vehicle (02) developed engine problems after a successful take off from Kourou, French Guiana, and crashed into the Atlantic Ocean. Lost with the rocket were two West German satellites, Firewheel and Amsat.

After evaluating the telemetry data ESA confirmed that one of the four engines of the L.140 first stage, engine "D", showed anomalies on two occasions: the first time at Ho (ignition) +5.7 sec and the second time at Ho+28 sec. The sequence of events was as follows:

Ho+3.3 sec:	Launcher lift-off.
+4.4 sec:	All four engines function nominally up to this instant.
+4.4 to +6.0 sec:	Chamber pressure of engine "D" begins to fluctuate by 4 bar, finally oscillating at an amplitude of + 11 bar at a frequency about 1000 Hz: on the films, this anomaly shows up as a yellow colouring in the exhaust. The mean chamber pressure remains nominal.
+6.0 to +28.3 sec:	Engine "D" is once again nominal.
+28.3 to +28.45 sec:	Recurrence of chamber-pressure oscillation of 7 bar on engine "D", showing up the same way on the films.
+28.45 to +63.8 sec:	Pressure of engine "D" once more nominal. A temperature sensor on the propulsion bay records a linear rise from 24° to 56° C.
+63.8 sec:	The temperature in question rises sharply to 100° C, and the chamber pressure of engine "D" falls simultaneously to 10 bar. Vehicle experiences a powerful roll torque.
+63.8 to +104 sec:	Flight control system succeeds in maintaining launcher in the nominal trajectory plane. Roll rate reaches 60° per sec.
+104 sec:	Fall in chamber pressure of engines "A" and "B", hitherto completely nominal. Engine "C" continues to function nominally.
+ 108 sec:	Fall in chamber pressure of engine "C" and destruction of launcher, probably initiated by the breaking of a structural connection as a result of considerable general stresses. Consequently, the self-destruct system fitted to each tank operates. Tank pressures had been nominal up to this point.

The third Ariane test flight had been scheduled for 7 November; at the time of writing it is not known if this will hold. Ariane's maiden flight on 24 December 1979 was highly successful.

LANDSCAPE OF VENUS

Based on data returned by Pioneer Venus, scientists are beginning to identify major features on the cloud-shrouded planet, and are working with an international nomenclature group to name them after mythical goddesses.

The orbiting spacecraft now has mapped a belt of terrain extending completely around the planet, except for a narrow strip of 38 degrees which is currently being filled. The spacecraft radar mapper instrument measures terrain from 75 deg North latitude to 63 deg South latitude. Pioneer is mapping 83% of Venus' total surface.

Investigators have identified two huge continent-like features on Venus. One centered at 65 deg North, is the size of Australia and contains mountains as high as Everest. The other, centred about 5 deg South of the equator, has somewhat lower terrain and is half as large as Africa.

The data show a variety of other features, including deep rift valleys, rolling plains, high plateaus and mountains.

Pioneer Venus has returned a huge volume of geographical information about Venus, and planetwide contour maps are currently being developed by the Massachusetts Institute of Technology, Cambridge, and the US Geological Survey, Astrogeologic Studies Branch in Flagstaff, Arizona. The mapping process involves converting continuous altitude measurements and radar images along the Pioneer orbital track to detailed contour plots and relief maps of the planet. This process requires error removal, orbit sorting and other types of data reduction.

Scientists have proposed that the northern highland mass be named *Ishtar Terra*, for Ishtar, the Babylonian goddess of love and war. *Aphrodite Terra* has been proposed as a name for the equatorial upland mass, after the Greek goddess of love – known to the Romans as Venus.

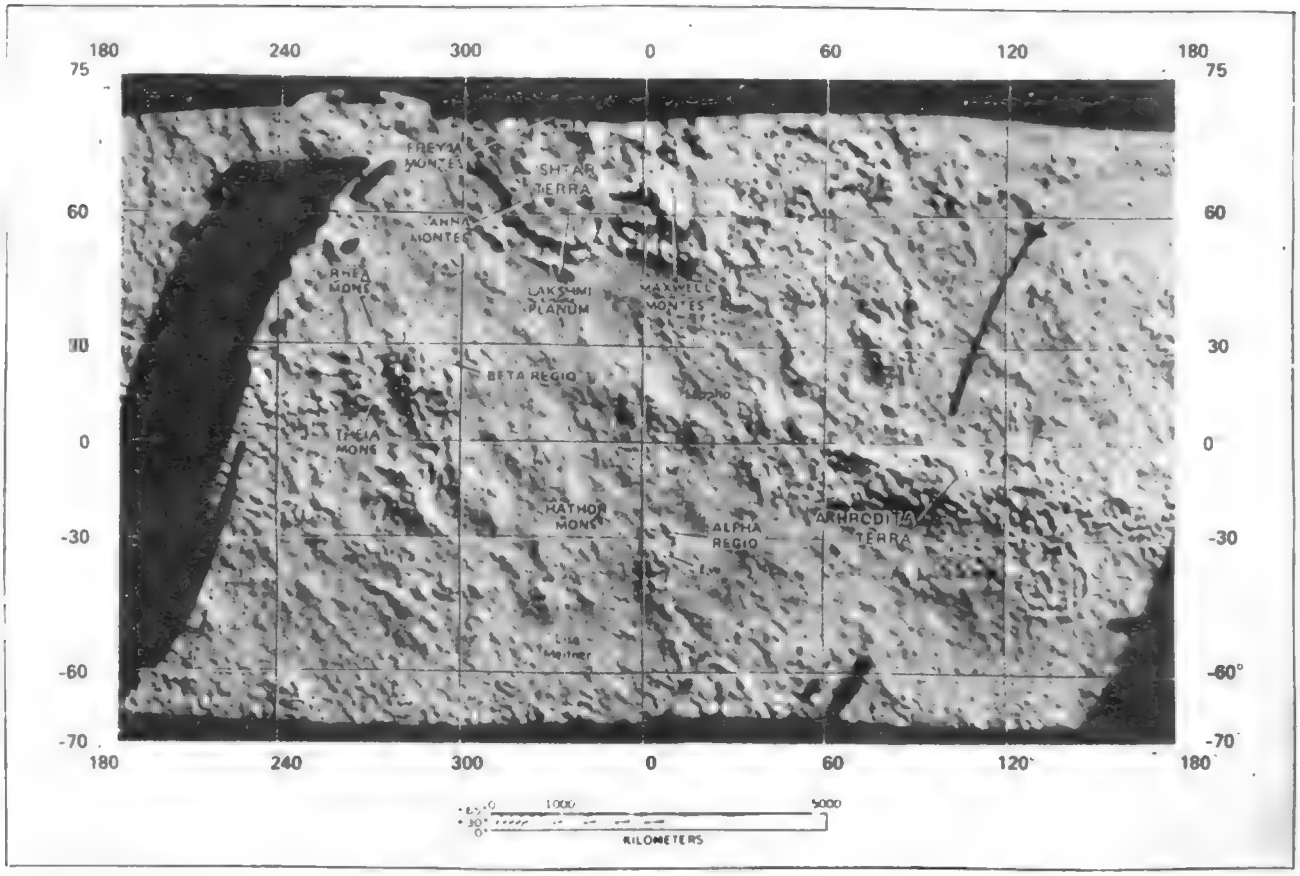
Ishtar was one of the Babylonian (Assyrian) trinity of major gods. Known as "the lady of battles," she often was depicted riding on a lion, weapon in hand. She was daughter of the Moon and sister of the Sun. Aphrodite (Venus), for whom the planet is named, is a major figure in the Greek pantheon.

The names for the two major features were proposed by the Principal Scientific Investigators of the radar mapping team: Dr. Gordon Pettingill of the Massachusetts Institute of Technology and Harold Mazursky of the US Geological Survey. They met with the Working Group on Planetary Nomenclature of the International Astronomical Union. The group has decided that nomenclature policy for major features on Venus should reflect mythical goddesses from various cultures. Minor features will be named for other mythical female figures, and still smaller circular features will be named for famous women who are no longer living.

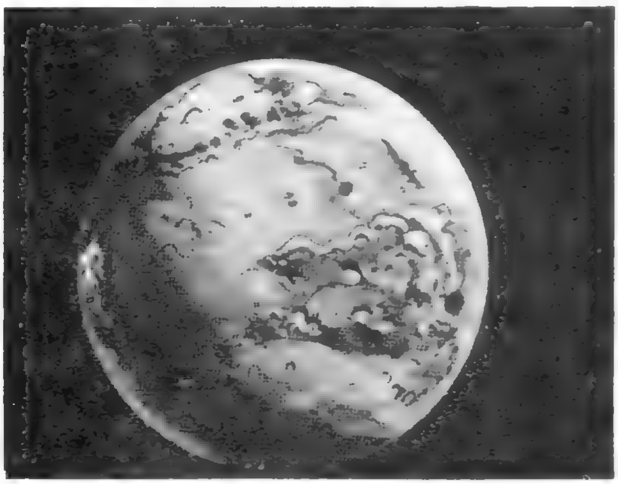
The astronomical union's working group has members from the United States, the Soviet Union and Canada.

Pioneer Venus has been circling Venus since December 1978, and is operating well. Another spacecraft – consisting of a carrier bus and four attached probes – arrived at Venus in the same month and penetrated the Venerian atmosphere.

Together, data from the orbiter and four probes are providing the most comprehensive information ever of the phenomenon that most visibly sets Venus apart from its "sister planet" Earth – its perpetual cloud cover and dense hot atmosphere.

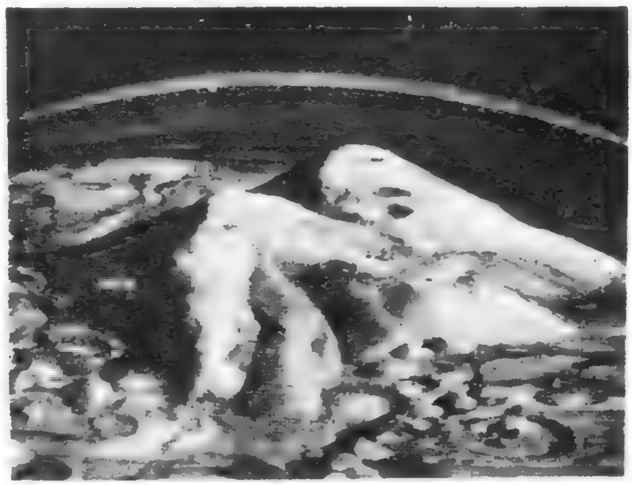


VENUS TOPOGRAPHICAL MAP. This countour map of Venus covers about 80 per cent of the planet's surface. The black curved gap at left was being filled in by the Pioneer-Venus Orbiter during April and May 1980. Before Pioneer, less than one per cent of Venus' topography had been measured (by Earth radar). Venus' topography consists of highlands, lowlands, and a huge planet-wrapping, rolling plain which covers about 50 per cent of the surface. The lowlands, which appear to be something like Earth's ocean basins, cover only about 16 per cent of Venus' surface, compared with about two thirds of the Earth's surface occupied by oceans. The range of altitudes on Venus is about 45,000 ft (13.7 km), from 9,500 ft (2.9 km) below "sea level" to 35,400 ft (10.8 km) above "sea level".

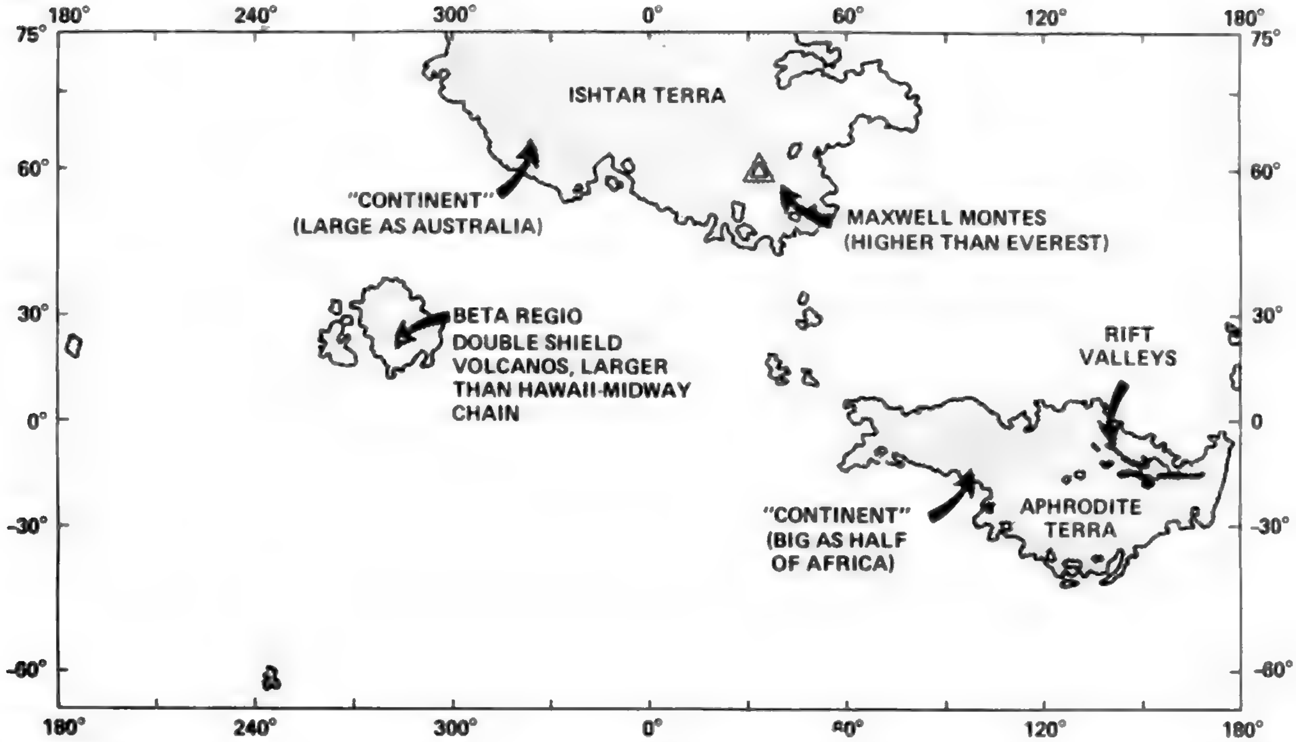


VENUS UNVEILED. Stripped of its opaque atmospheres, Venus would appear much like this. The artist's conception shows three continental-sized highland regions—*Aphrodite Terra* (foreground), *Ishtar Terra* (top), and *Beta Regio* (left). *Aphrodite Terra* is as large as half of Africa, and *Ishtar* is the size of Australia. The *Maxwell Montes* massif on the east end of the *Ishtar* plateau is the highest point on Venus, higher than Mount Everest.

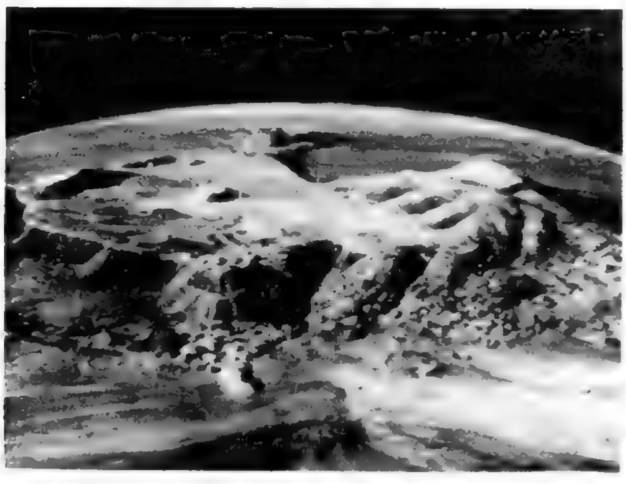
All pictures National Aeronautics and Space Administration



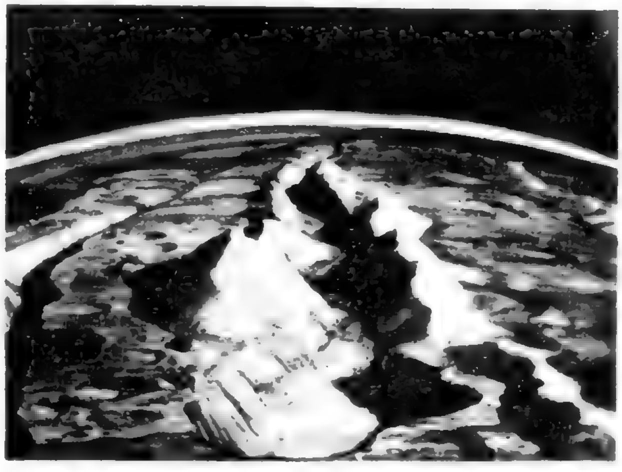
Rising up from the great plains, about 30 degrees north of the equator is Beta Regio—apparently two huge shield volcanoes, larger in extent than the Hawaii-Midway chain. This highland region covers a north-west distance of 1,300 miles (2,900 km). The two shield-shaped mountains making up the *Beta Regio* have been tentatively named *Rhea Mons* (the northerly) and *Theia Mons* (the southerly). Both are 13,000 ft (4 km) above the plains.



THIS SIMPLIFIED MAP covers about 80 per cent of the surface, from 75 deg N to 63 deg S latitude. The various features described and illustrated on these pages are easily identified. Though Venus has no oceans—as previously explained—the term "sea level" refers to the mean altitude of the planet's great plain. The *Aphrodite Terra* highland region near the equator is larger than *Ishtar*, as big as half of Africa. (Because it is a Mercator projection, *Ishtar* appears larger.) The Great Rift Valley is illustrated by an artist below right. The right flank of the large mountain on the left side of the main valley descends to the bottom of the rift. This slope drops at an angle of about 7 deg—one of the steepest slopes so far measured on Venus. The Rift is 175 miles (280 km) wide and 1,400 miles (2,250 km) long. This trench is roughly the same depth as *Vallis Marineris*, the great canyon on Mars. The Pioneer project responsible for this remarkable exploration is managed by NASA's Ames Research Center. The Pioneer-Venus Orbiter spacecraft was built by Hughes Aircraft Company. The radar-mapper instrument was provided by Massachusetts Institute of Technology, and the maps were made by the US Geological Survey.



Artist's impression of *Ishtar Terra*, the highest and most dramatic continent-sized highland region. *Ishtar* is a high plateau, embodying several mountain ranges, and about the size of Australia or the continental United States. The Western part appears to be a smooth plateau. Named *Lakshmi Planum* it is about 10,000 ft (3 km) above "sea level" (mean planetary radius). It is bounded in the west and north by mountains ranging upwards from 7,000 to 10,000 ft (2.1 to 3 km) above the plateau.



The Great Rift Valley (centre) at the east end of *Aphrodite Terra*, the continent-sized highland region just south of the equator. This valley and its smaller neighbour are the lowest regions yet found on Venus. The rift valley is about 9,500 ft (2.9 km) below the great plains. The adjoining rift valley (left) is slightly deeper than the main feature.

COLUMBIA'S THERMAL TILES

As readers will know – writes Gordon L. Harris – thermal protection has become the pacing item in NASA's reusable Shuttle programme. Earlier this year Sidney C. Jones, engineering manager of the Orbiter project for Johnson Space Center, said "recent thermal/loads analyses indicated the need to assess each of the nearly 31,000 tiles on 'Columbia' (first production model) as individual structural systems. These loads, resulting from aero, flight control and structural considerations, identified thermal and vehicle structural deflections that affected the tile system."

As a result, the projected date for initial launch has become rather vague – NASA says no earlier than 30 November 1980 and more likely February 1981. The uncertainty prompted the agency to buy more Delta expendable vehicles while the US Air Force ordered more Titan IIICs.

"Columbia" still occupies the Orbiter Processing Facility at Kennedy Space Center to which it was piggy-backed from California in March, 1979, short of approximately 10,500 thermal tiles. Rockwell International, prime Orbiter contractor, employs 1,200 in two 10-hour daily shifts at KSC to complete tile installation. That has turned out to be an arduous task, "Columbia" lacked 5,400 tiles in late May, 1980.

The explanation lies in those comments by Jones. Agency and contractor began to worry about the system's ability to withstand launch-related loads in October, 1979. A decision to "pull test" tiles beyond the estimated load limits revealed some deficiencies. Tiles had to be removed for rework while new tiles were affixed. The net gain in some weeks fell to 100–125 but moved up to the 500–600 level in April, 1980.

Since 1 December 1979, all new titles have undergone densification. The surfaces glued to a Nomex felt insulation attached to "Columbia" were treated with a silica-ammonia slurry, then baked twice for 24 hours. This process increased tile strength. KSC reported that at least 10,000 tiles have been densified.

Meanwhile some tiles have been damaged inadvertently by employees. Kenneth Kleinknecht, JSC manager at the launch base, believes as many as 1,000 will have to be replaced.

Three main hydrogen-oxygen engines installed in "Columbia" after static testing were removed in early May and returned to Mississippi for more "hot" firings. Each was to be operated for 520 seconds, the duration of burn for normal launch.

NASA decided upon the second firings because new turbopumps were installed after the initial tests and some welds had to be reworked. John Yardley, Shuttle programme director, said a supplier mistakenly included the wrong kind of welding wire in boxes shipped to Rocketdyne, the engine manufacturer.

Published reports in mid-May suggested that NASA might remove all tiles that have not been "densified" which would further delay "Columbia". An agency spokesman said, however, the ship will not require this further assurance for one flight.

It was planned, he added, to densify tiles between subsequent launches as Orbiter cargo loads increase. "Columbia" is expected to fly four test missions, launched in Florida and landed in California, then to undergo extensive modifications. "Challenger", second Shuttle off the production line, will take over in 1982.

DISPOSAL OF NUCLEAR WASTE

Nuclear waste disposal in space is being studied by the Boeing Company under a $296,000 contract from NASA's Marshall Space Flight Center. This supports the US Department of Energy's programme to develop technology for managing radioactive wastes in a safe and environmentally acceptable fashion. The space disposal option could supplement Earth disposal by removing from Earth the long-lived radionuclides which remain radioactive over tens of thousands of years.

A joint NASA/Department of Energy working group has prepared a preliminary four-year concept for a development and evaluation study plan detailing the activities necessary to reach an assessment of the space disposal option. The Boeing study will provide input for the first year of activities in this area.

If the programme plan is adopted, the Marshall Center will continue space system studies over the next four years, while the Department of Energy will be conducting parallel studies in the areas of nuclear waste systems, associated domestic and international concerns, and related assessments.

The four-year space option programme is expected to provide a systematic approach resulting in a thorough assessment of and plan for the space disposal option. The first year Boeing study will build on previous study results with emphasis on identifying, defining and assessing reasonable space systems concepts.

Studies of space systems concepts will include nuclear waste payload protection approaches, identification of space destinations, options for type of space transportation and launch sites, and payload retrieval techniques. The Boeing study is to be completed by December 1980.

SEA SURFACE SENSOR

A £116,000 contract has been awarded to British Aerospace Dynamics Group at Bristol by the European Space Agency (ESA). This calls for the study, for a period of at least six months, of an Imaging Microwave Radiometer (IMR) which will probably form part of the payload of COMMS – the Coastal Oceans Monitoring Satellite, writes N. E. Steggall. COMMS is one of the spacecraft that will feature in the Earth Resource Programme of ESA and is presently under consideration.

The IMR will be able to detect from orbit minute microwave emissions from the sea's surface. As all physical objects emit thermal radiation in the form of heat and also as radiation in the radar frequency band, the IMR will be detecting the radio frequency "heat". Therefore the IMR will be able to detect the variations caused by differing natural microwave emissions given off by both sea and ice surfaces. With all this new data scientists of oceanography, meteorology, climatology and glaciology, will benefit from receiving data regardless of their being any cloud cover whatsoever.

Using the IMR it will be possible for research establishments to study sea surface temperature; sea surface wind speed; atmospheric water vapour; atmospheric liquid water; rainfall, and sea ice coverage.

For this study British Aerospace are leading a team of European specialists – Dornier System GmbH (Germany); Electromagnetic Institute (Denmark); Ticra Aps (Denmark), and B & W Electronik AS (Denmark).

CHINA MOVES AHEAD

A three-stage version of China's CSS-X4 intercontinental ballistic missile is being developed for various space applications. Bigger than either the USAF Titan II and the Soviet SS-9 Scarp, it stands about 141 ft (43 m) tall and has a maximum diameter of 11 ft (3.35 m).

The rocket—to be known as "Long March 3"—has four gimbal-mounted engines in the first stage developing a combined thrust of some 280 tonnes. Stage two, supported by an

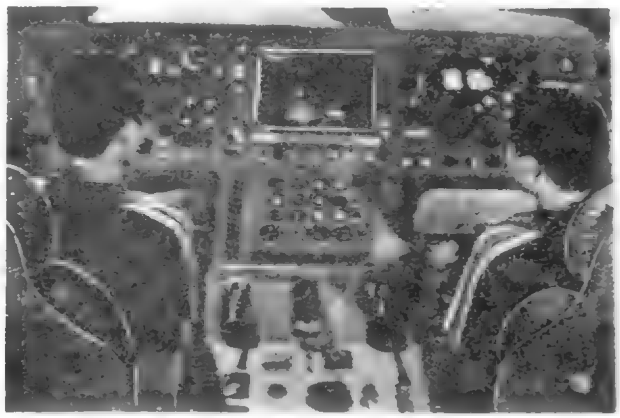
CHINESE ASTRONAUTS. An astronaut-candidate—possibly one of three selected for an early mission—is fitted with a spacesuit before entering a space simulator.

Astronaut-candidate ready for a test in the "environment chamber."

Like Soviet and US men of space, the Chinese astronauts undergo pre-flight training in a centrifuge.

Candidates check out some Chinese food specially prepared for space flight.

Clad in his spacesuit a Chinese astronaut prepares for a spin in the centrifuge.



Two candidates undergo training in a space simulator.

open truss framework, has a single engine of the same type with a vacuum thrust exceeding 70 tonnes. Four small gimbal-mounted motors provide thrust-vector control.

Both stages employ the storable propellants nitrogen tetroxide and UDMH.

The third stage, which employs LO_2/LH_2 propellants, has four gimbal-mounted thrust chambers.

The launcher will be able to send 800 to 900 kg payloads into geostationary orbit. China's first communications satellite is expected in 1981-82.

In the meantime pictures appearing in the *Hangkong Zhishi* monthly (April 1980) show preparations for manned space flight. They were supplied by our Belgian correspondent Theo Pirard.

IRELAND'S EARTH STATION

"A milestone in telecommunications development" – this was how a Government Minister described the decision by Ireland on 2 May to build a ground satellite station, writes Brian Harvey. The Earth station, costing IR£5 m (about £4.5 m sterling) will be built at Midleton, co Cork, in the south of the country. The site was recommended following a joint survey by the Government and COMSAT.

Government telecommunications Minister Albert Reynolds announced that a 60-acre site had been purchased. Work would be completed by 1983. The site was sufficiently large to allow further expansion that would meet satellite requirements until 2000, he stated. The ground station will allow direct access to satellite communications, thus freeing Ireland from dependance on cable and transit facilities in other countries. The initial intention was to meet circuit requirements on the North Atlantic and Europe.

The station is part of a Government plan to modernize phone services. At present, there is a 3-year waiting list for domestic phone installations and many rural areas in the west do not yet have direct dialling. The Minister has promised to rectify both problems by 1985. Ireland is heavily reliant on foreign – notably American – investment in industry, and good communications with home, European and world markets are regarded as essential.

Such a station can help offset the disadvantages of being a small island off a major land mass, and this may have implications for third world countries. As it is, Ireland is an active member of ESA, and a contributor to the Shuttle's Spacelab, and the OTS programme.

Contracts for the new ground station are expected to be announced shortly. Ireland is already a member of Intelsat, the international satellite consortium.

SATELLITE INTERCEPTION TEST

The test of the Soviet Union's satellite interception system during April 1980 was a more complex operation than might seem at first glance, writes Robert D. Christy. Indications are that four satellites may have been involved.

The first indication of the test being about to take place came with the launch of Cosmos 1169 by C-1 vehicle from Plesetsk on 27 March. It achieved an orbit of 476×515 km at an inclination of 65.8° and probably served as a calibration target for ground radars. It took no direct part in the actual interception manoeuvres.

Next, on 3 April, again by C-1 vehicle from Plesetsk, came the launch of Cosmos 1171 into a 966×1010 km, 65.9° orbit. This orbit compares with that of the target in the previous test of the system (Cosmos 967).

A wait of fifteen days then ensued until 18 April when at approximately 0040 UT, the interceptor—Cosmos 1174—left Tyuratam on an F-1 launcher. It achieved on orbit of 362×1025 km, 65.8°, leaving behind an intermediate rocket stage in a 140×432 km orbit.

At about 0411 UT on the same day, while on its second revolution of the Earth, it passed about 60 km from Cosmos 1171 about 1000 km above Leningrad. It was after this event that the fourth satellite came into the picture.

One and a half orbits later, when Cosmos 1174 was near perigee, it passed around 550 km from Cosmos 1167, a microthruster controlled (reconnaissance?) satellite which had been in orbit since 14 March. Cosmos 1167 was an F-1 launch from Tyuratam which had achieved an orbit of 428×444 km at 65.0° inclination. Use of the microthrust engine had ensured that it remained within a kilometre or so of its initial orbit up to that time. The orbits of Cosmos 1167, 1171 and 1174 were all in the same plane, and furthermore the nodal periods of 1167 and 1171 at 93.30 and 104.87 minutes respectively were in an exact ratio. For every nine orbits completed by 1167, 1171 completed exactly eight.

The closest approach of 1167 to 1174 occurred at 0639 UT and at the same time, a large manoeuvre by Cosmos 1174 altered its orbit to 380×1660 km at 66.1° inclination. The manoeuvre was reminiscent of those in previous interception tests which normally signal the actual interception.

The result of the modified orbit was a second close pass by Cosmos 1174 of 1171, at a distance of about 70 km, this time off the west coast of the US.

Finally, a very small manoeuvre by Cosmos 1174 on 19 April enabled it to intercept Cosmos 1171 yet again; this time the pass distance was within 20 km. It occurred over the eastern Pacific Ocean, near Easter Island.

Presumably Cosmos 1171 was the primary target in the experiment, although the obvious inference is that Cosmos 1167 was also involved; its role was probably more in the nature of an observer. The relatively distant pass of 550 km by Cosmos 1174 should probably not be classed as a true interception, but its occurrence and the relationships between its orbit and those of Cosmos 1171 and 1174 are unlikely to have been coincidental. Also, in the cases of all three interceptions of Cosmos 1171 by 1174, Cosmos 1167 was between 4500 and 5000 km away at the times of the events and could easily have monitored them.

The final event of the test was the disintegration of Cosmos 1174 into a dozen or so fragments on 20 April.

The orbital and time data presented above are based on calculations using Nasa Goddard Space Flight Center's "Two Line Orbital Elements". Owing to the need to extrapolate certain of their figures and to the calculation methods, the miss distances are accurate to within about 10 km.

Mr. Christy would welcome information from other observers on the behaviour of the Cosmos satellites mentioned in this report. Further experiments in the series are awaited with interest.

SPACE FOR THE "AGED"

Can humans older than 55 withstand the physiological stress of weightlessness riding aboard NASA's Space Shuttle? To answer that question, the space agency for the first time is subjecting males aged 55 to 65 to prolonged bedrest, a way to simulate the weightless environment of space flight.

The test subjects are the oldest NASA has subjected to simulated weightlessness. Four previous studies at NASA's Ames Research Center tested males and females aged 35 to 45 and 45 to 55. Women aged 55 to 65 will be tested later this year, completing the planned series of six studies designed to set baseline medical criteria for space-flight participation.

Forty-six males, aged 55 to 65, reported for the first briefing at Ames in early February. Of the 44 who reported for physical examination, 25 were found fit enough to participate in preliminary testing – 10 of these were in the 60-65 age group. Twenty were selected to report for orientation on 24 March, with the other five serving as alternates.

The preliminary orientation and testing serves a dual purpose: it gives Dr. Harold Sandler, Ames project scientist, an opportunity to see how subjects perform and it also allows the subjects an opportunity to decide whether they want to participate.

Two sets of four subjects were selected on 7 April. Four were admitted on 10 April to Ames' Human Research Facility for nine days of controlled observations, 10 days of bedrest and five days of recovery and post-bedrest tests of the cardiovascular system. Another four subjects were admitted 13 April for the same sequence of events.

THE EROS DATA CENTER

For the last eight years the EROS (Earth Resources Observation Systems) Data Center has served as the principal facility for the storage, reproduction and dissemination of Earth resources imagery and photography in the United States, writes Keith T. Wilson. The Center has also played a significant role in the training and assistance of data users. The Center's archives contain well over six million images and photographs of Earth surface features. These have been taken by three unmanned Landsat spacecraft, manned Gemini, Apollo and Skylab spacecraft and also high-and-low-altitude aircraft.

Last year saw some significant new developments at the Center. In February 1979 the EROS Digital Image Processing System (EDIPS) became operational. This has changed the Center's procedure for creating a Landsat image archive. Radiometrically and geometrically corrected Landsat digital data are now received from Goddard Space Flight Center. Previously 70 mm film chips were sent. The digital data are processed through EDIPS and are recorded on 241 mm film by a high resolution laser beam.

In May 1979 the EROS Data Center activated its recently RCA installed Earth station which receives Landsat data relayed from Goddard Space Flight Center via a domestic communications satellite. The new antenna and receiving station eliminates the need to send Earth resources data by mail, thereby minimising the time between initial acquisition of data by the Landsat sensors and delivery to the EROS Data Center for image processing.

In addition to these developments improvements have been made regarding access to Landsat data. Foreign ground receiving stations have begun to exchange their information with the Center and data from the Italian and Brazilian stations have been stored in the Center's archives. Also a computer network has been developed which links the EROS Data Center's computerized information file with various US Government and commercial users. These users can now conduct searches of the Center's information file for the data they require.

Readers wishing to obtain Earth resource imagery and photography should write to the following address for ordering and pricing information: User Services, EROS Data Center, US Geological Survey, Sioux Falls, South Dakota 57198, USA (Please enclose SAE or International Reply Coupons).

The Earth Resources Observation Systems (EROS) Data Center, located on a 318-acre site amidst the farmlands of south-eastern South Dakota, provides public access to image products acquired by US space and aircraft programmes associated with Earth resources.

USGS/EROS Data Center

Millions of images of the Earth are deposited at the EROS Data Center. The facility houses a satellite data receiving antenna, a digital processing system, master data archives, a precision photographic reproduction laboratory, and a computer complex. Staff includes applications scientists and analysts engaged in training, transfer of technology, and special projects "to further the understanding and applications of remote sensing."

INDONESIAN SATELLITE AWARD

Hughes Aircraft has been chosen by Perumtel, Indonesia's Government-owned telecommunications company, to build a new generation of Palapa communications satellites to succeed the Hughes-built system placed in orbit in 1976/77. The announcement was made in Jakarta by Indonesia's Minister of Communications.

The new satellites will be more than twice as big and four times as powerful as those which enabled Indonesia to link its many islands by space-age communications. Hughes will build two of the new satellites, as well as associated equipment. The two contracts involved total about US$80 million.

The new satellites will be able to serve Indonesia and countries of ASEAN (the Association of South-East Asian Nations) and also Papua New Guinea.

The satellites are designated Palapa B-1 and B-2. They will provide voice, video, telephone and high speed data services, employing flight-proven technology throughout. The new satellites will have 24 transponders each compared to 12 for the present model. Each of the new transponders will have 10-watt power output, compared to five watts for those now in use.

The new models have outer cylindrical sleeves which, along with folding antennae, deploy in space. The vehicles' cylindrical bodies and their extensions are covered with solar cells. The arrangement nearly doubles the area of power-producing solar cells usable with the same size satellite. The vehicles are about two storeys tall when deployed in space. In-orbit mass at the start of the satellites' 8-year mission lifetime will be about 630 kg.

The new satellites will be the ninth and tenth in the HS-376 product line. Hughes is building the basic model HS-376 for the Anik C and Anik D series of communications which will provide communications services to business customers in the United States.

The satellites will be built at the Hughes Space and Communications Group facility in El Segundo, California. To date, Hughes has launched 36 commercial communications satellites, more than any other manufacturer.

CORRESPONDENCE

Space Disposal of Nuclear Waste

Sir, Disposal of high activity nuclear waste material in space has been studied extensively here. Hence, I wish to comment on D. H. Hinson's fine paper (*Spaceflight*, April 1980):

- Using thermal energy from the nuclear material to heat up hydrogen for space propulsion (similar to the well-known Poodle proposal) may be applicable.
- Solar sails are a suitable means of propulsion to reach the Sun.
- Depot storage in sufficiently high Earth orbit seems to be a very good alternative.

Costwise, this space application appears to be practical; main difficulties have to do with safety in case of Earth launch failure – I think, we talk possibly of a time frame after the year 2000, when sufficiently high launch reliability has been demonstrated.

More detail is contained in Vol. 1 of my forthcoming book *Die grenzenlose Dimension – Raumfahrt*, Econ, 1980.

PROF. DR-ING. H.O. RUPPE,
Lehrstuhl für Raumfahrttechnik,
Technische Universität München.

Sir, I found the article by David Hinson on the Disposal of Nuclear Waste (*Spaceflight*, April 1980, pp. 182–184) of immense interest. My view on the options described is that ideally:

(a) We should *not make* use of nuclear energy until we have found a way of avoiding the formation of undisposable and dangerous waste, but

(b) It would be much better to dispose of such waste on the Moon (first choice) or in solar orbit (second choice) if it is deemed essential to use power that does produce this waste.

The ideas described in the article, may, in fact offer a solution to this problem for the time being and are really very interesting suggestions.

H. C. WHITBREAD,
Plaistow,
West Sussex.

Disposal of Nuclear Waste

Sir, In the March issue of *Spaceflight* was an article by David Hinson concerning the disposal of nuclear wastes in space. There are two points I would like to make.

Firstly, during a recent visit to England, I read that the first experiments in using a fast breeder reactor to incinerate nuclear wastes will be starting this year, so Mr. Hinson is a little pessimistic in calling this technique infeasible with present technology. Interestingly, these joint British-American experiments will be using the British fast nuclear reactor in the North of Scotland, as the campaign against fast breeder technology by several US administrations has prevented the construction of such a reactor in the US.

Secondly, although such articles as Mr. Hinson's are technically interesting, the problems surrounding nuclear power are not technical, but social and political. These centre around the acceptance of the real total costs of modern technology by the members of societies that benefit from it, and the general level of scientific illiteracy in the, I suspect, majority of those members.

In all the anti-nuclear power propaganda, I have yet to see a definition of what an acceptable level of reactor safety would be, and more important how would it compare with means of generating electric power that are currently accepted. For example, during the Harrisburg accident several miners were killed in a nearby coalfield, but no one suggests closing down coal-powered generating stations.

Unfortunately, few of our legislators and communications personnell seem to have a technical or scientific training that would allow them to inform the population at large about the real state of the balance of technology and the standard of living in a modern society.

DR. DAVID G. STEPHENSON,
Max Planck Institut für
Aeronomie,
Katlenburg Lindau,
Federal Republic of Germany.

Sir, Thank you for David Hinson's interesting article on the disposal of nuclear waste in space (*Spaceflight*, April 1980). It is clear that the disposal of such waste in space has many advantages provided that it can be safely launched from Earth, which is, I think, the crucial point.

Much, perhaps most, of the argument against nuclear power is centred around the transportation dangers of highly active waste. The use of the Space Shuttle to carry these materials into orbit will, justifiably, cause some concern and may not, therefore, prove acceptable from environmental or political viewpoints. We must realise, however, that the other options may be just as dangerous, particularly in the long term. It would seem to be a case of choosing the least of several evils and it might be better if we don't place ourselves in a position where we have to make that choice.

There seems to be little point in expanding our nuclear industry to the stage where the disposal of waste on a massive scale becomes necessary. A limited number of nuclear power stations may be required to see us through to the time when fusion can be exploited and solar power satellites built, but it is the latter two sources of energy that are our best bet for the future.

IAN CRAWFORD,
Warrington,
Cheshire.

Sir, I read your article on the options of nuclear waste disposal in Space with interest. You have, of course, presupposed the use of a fairly extensive nuclear power porgramme – a suggestion that is still very open to controversy.

Certainly nuclear power is not the most attractive of future's because there is always an element of risk, no matter how small. Let us hope, therefore, that alternative energy sources can be developed and that the problem of waste disposal does not grow. Unfortunately, this may not be realistic and the extra-terrestrial option of waste disposal seems a good one, until one analyses the cost. Unless space travel can be made a good deal cheaper, then your suggestions must surely be economically unviable. One mistake could prove very costly if a recovery were attempted, and if it were not, would it be ethical or safe to abandon waste to outer space. I think not.

The possibility of a lunar disposal site seems the most likely. I hope we would choose a "soft landing" programme (despite the cost) and avoid contamination of any surface area. We have savaged our own planet, now is the time to set higher standards for the future.

R. J. ADAMS,
Aylesbury,
Buckinghamshire.

"Return to Apollo"

Sir, I read with interest the article "Return to Apollo" by Andrew Wilson and David J. Shayler (Spaceflight, January 1980), particularly the speculative "what-if" sections. I would like to comment on the hypothetical crews given for Skylab and the cancelled Apollos in Table 6.

The Skylab selections are hard to fault, based as they are on actuality, and the same applies to those for Apollos 17 and 18 as they had been the back-ups for 14 and 15.

However, I would question some of the authors' selections for Apollos 19 and 20. These were:

Apollo 19	Lovell	Swigert	Lousma
Apollo 20	Haise	Weitz	Musgrave

Like the authors, I have no "inside" information and am relying only on published sources so, in making the following points, I point out that my conclusions are strictly personal opinion.

Firstly, Lovell indicated shortly after Apollo 13 that he would not fly in space again unless he and his crew were requested by NASA to repeat their specific mission [1]. This assignment was given to Shepard and his crew (that is, the *Fra Mauro* landing site). Also, a crew including both Lovell and Swigert would break the precedent of the veteran-commander-and-two-rookies combination which had been followed since their own Apollo 13 flight, as well as the fact that a CMP would normally expect to command his next mission. A further consideration is that, having flown Schmitt on Apollo 18, it would seem likely for the LMP position to continue to be occupied by a scientist.

Following the departure of Lovell, all of these other factors fall into place almost automatically. This allows Swigert, as well as Haise, to command his own crew and the "promotion" of Lousma to CMP on Swigert's crew, opening the LMP spot for a scientist; Weitz is retained as CMP under Haise.

The authors state that Musgrave has been the "most prominent" of the group 6 astronauts and if this is so he could be moved up to Apollo 19, but we must remember the scientists' specialties. Musgrave was back-up Skylab 2 science pilot probably because he is a doctor (of medicine) – as is Kerwin, his opposite number in the prime crew [2].

More appropriate for lunar missions would be Allen (physicist) and England (geologist and physicist), particularly as they served as Mission Scientist on Apollos 15 and 16 respectively [2].

Taking all this into account gives the following:

Apollo 19	Swigert	Lousma	Allen
Apollo 20	Haise	Weitz	England

The possibility also exists, of course, that if Musgrave does have some sort of priority as the authors suggest, then Lenoir could have followed him on Apollo 20 as he, too, was a back-up Skylab science pilot. However, it's worth noting that his specialty (electrical engineering) also parallels those of the SPTs of the corresponding prime crews [2] which probably accounts for his selection.

Incidently, the Swigert-Lousma pairing is an appropriate one as it was to Lousma as CapCom that Swigert reported "we've got a problem" [3].

CHRISTOPHER RILEY,
Mount Albert,
Victoria,
Australia.

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1. Lovell, "I Was a Good Target for the Law of Averages", *Life*, 11 May 1970.
2. David J. Shayler, "Where Are They Now – Part Four", *Spaceflight*, March 1979.
3. George Alexander, "Apollo 13: Three Who Came Back", *Newsweek*, 27 April 1970.

Double-Cosmos Launches

Sir, It has been suggested [1] that the Double-Cosmos launches made by the Soviet Union, i.e. Cosmos 881/882; 997/998 and 1100/1101, are tests of a Soviet boost-glide, lifting body or even a shuttle vehicle. If we, as an assumption, accept that explanation it does not explain why *two* such craft have been launched by the same Proton launch vehicle. The reason for releasing two *identical* spacecraft from the launch vehicle upon orbital insertion is indeed obscure. (Fig. 1 shows that the two craft separate immediately after injection.) Why try a simultaneous complex re-entry of two identical and complicated space vehicles when there should be sufficient data to be gained from one?

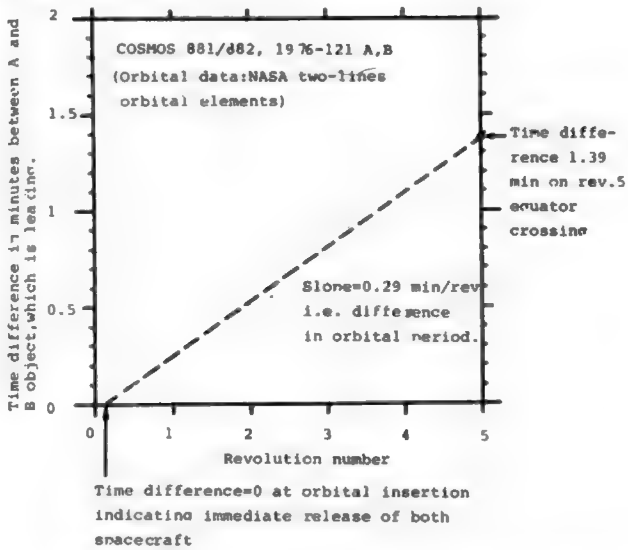


Fig. 1. Data indicating that two spacecraft separate immediately after orbital injection. (Cosmos 881/882.)

Sven Grahn

The fact that two vehicles indeed do re-enter simultaneously is more easily understood if the two craft are *not identical*! I would like to offer the explanation that one of the objects is a non-lifting, maybe spherical, object which is tracked by radar to obtain atmospheric density data from which the lifting-body characteristics of the other re-entry vehicle can be accurately deduced. The recoverable spherical body could also be equipped with accelerometers and a "hardened" tape recorder to obtain data during the "black-out" period of re-entry when radar transponder contact may be intermittent.

SVEN GRAHN,
Sollentuna,
Sweden.

REFERENCE

1. Trevor Williams, "Soviet re-entry tests: A winged vehicle?," *Spaceflight*, May 1980, pp. 213–214.

ERRATUM

In the Report of the 34th Annual General Meeting (*Spaceflight*, June 1980, page 266), the second paragraph from the end should have referred to the Society's 50th Anniversary in 1983. Professor Groves made the point that the occasion would be celebrated in an appropriate manner. The possibility of holding another IAF Congress in the UK, funds permitting, was under review but "we would envisage holding a Congress after that date."

An interplanetary link?

Sir, I suggest that the mysterious Cosmos 881–882 (15 December 1976), 997–998 (30 March 1978) and 1100–1101 (23 May 1979) have prepared the way for future manned interplanetary missions [1], including a Venus and Mars fly-by by a Soviet space station. For Earth return, two capsules with crew onboard would separate from the station just before encountering the Earth atmosphere.

The short duration twin Cosmos missions were perhaps to test the separation mechanism between the two capsules and an imaginary station, then the return to Earth.

JEAN-JACQUES LATAPIE,
Villelongue,
France.

REFERENCE

1. "Future of Space Stations", *Spaceflight* September/ October 1978, p. 325.

Fate of Zond 4

Sir, The response of Mr. N. L. Johnson to my comments on his article concerning the whereabouts of Zond 4 certainly requires a further remark. [1, 2, 3]

The Satellite Situation Report (SSR) keeps note of all objects in orbit that have (of course) been detected by the NORAD SPADATS Network. Objects continue to be listed – with or without the maintenance of elements – as long as they are in orbit, geocentric, heliocentric or otherwise. Decayed objects *cease to be listed*. One might make particular note of the fact with respect to interplanetary spacecraft; their elements are not maintained on a (published) daily, weekly or even monthly basis. If they decay onto a planetary surface they are removed from the "objects in orbit" list and a note is made that they (it) landed on said planet. There is also published, now irregularly, a decayed objects list. *Zond 4 does not appear on it*; however, parts B, C, D, of the Zond 4 launch event came down on March 7, 7, 5, 1968 respectively and are so listed in the last decayed objects list of 31 December, 1978, Vol. 18, No. 6, ten years after the event (they also appeared in prior decayed objects lists). Therefore, the remark, "current elements not maintained" means just that: the object is in orbit but, at least in the open press, the elements are not published. Furthermore, Object 1968-13A, Zond 4, is still actively listed as an orbiting object in the SSR of 31 August 1979, Vol. 19, No. 4. Are we to believe that both NORAD and NASA are lying to us? I think not!

Insofar as Mr. Johnson's display of irritation with private communications is concerned; this is not an uncommon manner of stating that a source does not wish to be or cannot be revealed. Such sources may be without value to Mr. Johnson – I would not deign to deny him his opinions – but I find the sources quite priceless and am happy to have them despite the severe restrictions on identification. I would add further that I dispute the disgruntled remark stating that I am baiting anyone. The private communication reference, for me, is a way of stating that I am not playing guessing games and do have an (unfortunately) non-revealable source, no more, no less!

SAUNDERS B. KRAMER
Maryland,
Gaithersburg, USA

REFERENCES:

1. *Spaceflight*, Corresp., January 1980.
2. *Spaceflight*, July 1979.
3. *Spaceflight*, December 1978.

"The Philosophy of Survival"

Sir, I have read with interest the article "The Philosophy of Survival" by Michael W. Taylor in the February issue of *Spaceflight*.

Unfortunately it is a rather dogmatic essay giving the impression that "Creative Evolution" is a foregone conclusion and that Russell's statement quoted has to be the basis of any future view. The truth of the matter is that the question of the inter-relationship between "Matter", "Energy" and "Mind" has probably never before been "in the melting pot" to such a degree and current investigation on the fringes of scientific knowledge could well result in the necessity for a drastic re-think of basic assumptions concerning the Universe.

It is probably Man's destiny to expand into the incredible Cosmos about us and it may be that we shall find a key to the almost insoluble problems of interstellar travel and beyond.

A. P. BLACK,
Wendover,
Buckinghamshire.

Progress Re-Entries

Sir, Michael Richardson [1] raises a question concerning my calculation of the retro-fire and re-entry times of Progress 5 [2].

To my eternal shame, I have to admit to a typing error in the original script of my letter. The re-entry date of Progress 5 should read 1979 April 4 as he rightly points out. Otherwise the remaining data concerning equator crossing, etc, stand as printed. They are based on the last set of orbital elements issued for the object by Goddard SFC, in the early hours of 4 April.

Mr. Richardson's letter is the first place that I have seen a retro-fire time for Progress 6 other than my own calculation, again from Goddard's elements. I am pleased to see that my figure of 1857 UT on 1979 July 20 [3] is not too far removed from the true one of 1851 UT. In this case, the final set of Goddard's elements was issued only two orbits before the event occurred. The time difference between the calculated and the actual times might result from a maneouvre to a low orbit for the last couple of revolutions around the Earth. If this is so, one or two of my other estimates may be out by a similar amount.

I cannot emphasise enough though that, except where the Soviets have actually issued details of the timing of events, any information computed by such as myself consists only of estimates based on the best available information and using comparison with other events as a guide.

ROBERT CHRISTY,
Lincoln, England.

REFERENCES

1. Michael Richardson, "Progress Retro-fire Times" – Correspondence, *Spaceflight* 22, 5, p. 226, May 1980.
2. Robert Christy, "Progress Spacecraft – Times of Re-entry" – Correspondence, *Spaceflight* 21, 10, p. 430, October 1979.
3. Robert Christy, "Progress 6 and 7 Re-entries" – Correspondence, *Spaceflight* 22, 7–8, p. 300, July-August 1980.

Living in Space Colonies

Sir, In the April *Spaceflight* John Allison asks whether the environment in a Space Colony might not be so restricted and artificial, divorced from "nature", that its inhabitants might find conditions intolerable after a short while. May I use your columns to air a few thoughts?

First of all, as I understand it, the idea of having to "commune with the natural wilderness" is historically a local idea, associated with the Romantic Movement in art. The Enlightenment found it perfectly acceptable that we should want to live

in a wholly tamed and controlled artificial environment. Indeed, "artificial" was a term of approval and not approbation.

Next, as I understand it, the intention of the Space Colonists is to build an environment big enough to contain a variety of landscapes within it. It seems to me probable that after a while, if it is possible at all, it will be wealthy enough to permit vacationing elsewhere - the Moon or even the Earth. After all, for it to be possible at all we have to think in terms of a considerable reduction in space transportation costs than are available in 1980. My thought anyway is that the early colonists may not see themselves as forever leaving Earth, but going and living in the Colony for a while. When the "while" averages at perhaps ten or fifteen years there will be some who never leave, others who will be born and grow up there, and could well look on Earth as a rather messy and unhygienic place to want to live in.

Colonies on the Moon may be differently placed. They may not immediately offer so much interior space, but they will be in direct contact with the natural wilderness. I suspect that that environment may shape the internal values of the community away from ideas that we consider "natural."

But finally I see a very real way in which Space Colonists can "get away from it all." Solar sails may or may not have an economic role in opening up the Solar System, but to a Space Colony located high in Earth's gravitational field they may provide a natural form of recreation. Small space yachts, using sunlight for their propulsion and the skills of their pilots to tack them within the Earth-Moon system could swing low over the Moon and Earth to give their crews dramatic views and a feeling of grappling with natural forces and danger, and I have no doubt in due course become the hazard to normal shipping that their analogs on Earth from time to time become. Once again I realize that Arthur Clarke has been here before me, but I feel that "sunjamming" has all the qualities needed for weekend participant sport.

I also hope that whatever shape the Space Colonies eventually become, they will have the space down the middle for "man powered flying" that the original O'Neill concept contained.

BOB PARKINSON,
Aylesbury,
Bucks.

Living in a Space Colony

Sir, Reading Mr. Allison's letter [1] I can only conclude he has not ready any of the literature on the subject of space colonies [eg 2, 3] or given serious thought to the possibilities. As a nature lover and a country boy myself, I have travelled to many of the world's beauty spots, so I fully appreciate that terrestrial scenery and wildlife is often beautiful and awe inspiring. Nevertheless, I would dearly like to spend a few years in a space colony for those very same reasons!

Astronauts invariably emphasise that the view of the Earth from space is an experience so beautiful that words cannot describe it. I understand that the Skylab astronauts would gladly have spent the entire duration of their stay in space staring out of the window at the panorama passing below. Further, consider the spectacle of a total eclipse of the Sun, an event alas that I have not yet seen. Eclipses of the Sun by both the Earth and the Moon would be commonplace from a colony at either the L-4 or L-5 point.

Has Mr. Allison ever considered the scope for recreation in low gravity or weightlessness, such as that existing on the rotational axis of O'Neill type space colonies? Any sport you care to name would be much more fun without the restrictive pull of gravity. For example, in a low gravity swimming pool even sinners like me could walk on water! Man powered flight would be trivial without the need for complex Gossamer Condors or Gossamer Albatrosses, and hang gliding could be indulged in with much less danger than on Earth.

Those unfortunates suffering from weak hearts would probably welcome the chance to live in an idyllic low gravity colony, where a heart relieved from fighting gravity would work for longer, allowing longer retirements. With a permanent shirtsleeve environment the elderly need not fear hypothermia. Without stormclouds there would be no need for cumbersome winter overcoats or umbrellas.

From time to time space colonists may visit the Moon. What could give more "spiritual pleasure" than visiting Tranquility Base, or sitting in the driver seat of Apollo-15's lunar rover overlooking Hadley Rille? Similarly one could take the occasional spacewalk. Imagine the experience of hanging in space at the end of an umbilical surrounded by nothing but stars.

CHARLES F. RADLEY,
Wherstead,
Ipswich.

REFERENCES

1. J. Allison, Correspondence, *Spaceflight*, April 1980, p. 187.
2. T.A. Heppenheimer, *Colonies in Space*, Warner Books, 1977.
3. G. K. C. O Neill, *The High Frontier*, Jonathan Cape, 1977.

Destiny in Space

Sir, I write in strong support of Gerald Borrowman's article in *Spaceflight* for April 1980. But I also think that, of the four conditions he cites as necessary for a major new advance, the three he believes currently exist in the US are also to be found in other parts of the Western World, notably in France, Germany and the United Kingdom. Moreover, with the European Space Agency's recent success in launching Ariane, there would seem to be a specially propitious climate for increased transatlantic cooperation.

What is more, it seems rather obvious that such cooperation could have an important political as well as scientific value. At a time when far too many of our nations are bickering among themselves about trivialities, while (apparently) paying far too little attention to some of the most dangerous world trends, any project that could help bring us all closer together would surely do no harm.

A particularly valuable project might, I suggest, concern a new, jointly operated, Spacelab.

However, one word of caution. Gerald Borrowman reminds us of Shakespeare's famous homily "There is a tide in the affairs of men . . . etc". Without wishing to dampen anyone's enthusiasm, but only to counsel that enthusiasm be tempered with prudence, may I recall that Shakespeare put those words into the mouth of Marcus Junius Brutus. And look what happened to him!

BRUCE M. ADKINS,
Gif-sur-Yvette, France.

The Ralph Smith Paintings

Sir, I wonder whether any of your readers with long memories could help clear up a minor mystery?

On pages 84 and 107 of my recent book *HIGH ROAD TO THE MOON* I reproduce paintings by R. A. Smith which have characteristic three horizontal coloured stripes in the top left-hand corner. Having seen the originals I can confirm that the colours are just those which might be expected if the paintings had been intended as covers for the American *Magazine of Fantasy and Science Fiction*. However, neither myself nor artist David Hardy (both long time readers of *MoF&SF*)

can remember seeing an R. A. Smith *F&SF* cover. So I would like to ask, does anybody know the story behind these pictures? Did Ralph Smith ever appear on the cover of *MoF&SF* in the early Fifties, or were these pictures unsuccessful attempts to break into the US market, or what?

R. C. PARKINSON,
Aylesbury,
Buckinghamshire.

Sir, Bob Parkinson has raised an interesting point concerning two of Ralph Smith's paintings in *High Road to the Moon*: were they originally intended for the front cover of *MoF&SF*?

Unfortunately, the answer would appear to be No! Smith produced them as preliminary paintings (in colour) for the space sections of some Annuals years ago, but they were apparently never used. The three coloured stripes were there for the printer to achieve the correct colour registration in reproducing the pictures. On these two occasions Smith put them within the pictures' boundaries but the final versions intended for publication would not, of course, have had the stripes.

Incidentally, readers may like to know that [1] contains a number of Smith's paintings in colour – they are even more interesting than in black and white.

ANDREW WILSON,
Rotherham,
South Yorkshire.

REFERENCE

1. *The Exploration of the Moon*, R. A. Smith and A. C. Clarke, Frederick Muller, 1954.

34th Annual General Meeting

Sir, I was appalled to read in the June issue of *Spaceflight*, that not being happy in almost destroying our first English tradition of Cricket, we now have "Packerism" in the midst of our beloved Society. What on this Earth persuaded so called responsible members of our Society to waste the valuable time of its committee in requesting details of all its members to suit their own ends; namely to form some sort of "breakaway" group. By the pedantic use of some outdated imperialist dogma, they have nearly ruined the fifty years of tradition and standing afforded to its members. What will this so called "London Group" want next, a change of name? How about the British Interplanetary Autonomous Collective; or the British Interplanetary Anarcho-Syndicalist Commune.

I notice that this application for members names and addresses was done by one person on behalf of "others". Well let us have the names of these others so that we know who the "moles" are in our midst.

For those who complain that there are not enough meetings, I can only say that those of you who live in London do not know how lucky you are. What about the guys who live in Cornwall or Scotland who never get a chance to go to meetings at all. I envy you. I work a twelve hour day from eight a.m. to eight p.m. so I could not get to meetings even if I wanted to.

If the object of the "London Group" is to stir up members, they have gone about it the wrong way. We may be silent, and appear in the background, but given unhealthy criticism we would all band together, I am sure. As to the membership fee you can gladly double it, and it would still only be one six-hundredth of my salary, and worth every penny.

D. J. BASSETT,
Upper Stratton,
Swindon,
Wiltshire.

Sir, It was with astonishment that I read the report of the 34th Annual General Meeting and the "goings-on" which occurred during it.

No doubt Mr. MacKinlay needed the list of members to solicit support. I was glad to see that he eventually withdrew his request for the list.

It is obvious from their actions that the dissenters have no idea of how to conduct themselves within a professional body and the best thing for all concerned is for them to resign.

I have been a member of the Society for 30 years and proud of it. I have nothing but praise for the way the Society is managed and for the aims it strives for.

RODERICK D. MILLER
(Fellow),
Rayleigh, Essex.

"Ill-advised" Moon Treaty

Sir, I was most disappointed with the incomplete and mislead ing article on the UN "Moon Treaty" in the *Space Affairs* section of the November 1979 issue of *Spaceflight*.

The draft UN treaty on the Moon and other celestial bodies extends its mandate not just to the Moon, but also to every moon, planet, and asteroid in the Solar System (and possibly beyond, since the outer limit of the Solar System is not defined by this document), to all possible orbits around them, and to all orbit to orbit transfer trajectories. It prohibits the non research utilization of lunar resources except as performed by an "international regime"[1].

The pages of *Spaceflight* have often carried reports on projects that could not even be attempted if this document becomes an accepted part of the body of international law. The assembly of large space structures from lunar and asteroidal materials, the "mining" of the atmospheres of gas giant planets, commercial space transportation, and any kind of space manufacturing would all be declared to be illegal. (The Daedalus project appears to be safe; its purpose is entirely scientific research.)

In the United States the L-5 Society and others have been leading an effort to prevent Senate ratification of this ill-advised Moon Treaty.

JOHN E. CAMPBELL
Hood River, Oregon, USA

REFERENCES

1. Art Dula, "Free Enterprise and the Proposed Moon Treaty", *L-5 News*, October 1979 & November 1979 (two parts).
2. Jerry Pournelle, "The Alternate View: The Moon Belongs to Everyone", *Analog Science Fiction/Science Fact*, January 1980, pp. 135-139.
3. K. Eric Drexler, "Dangerous Defects in the Draft for a UN 'Moon Treaty' ", *The New York Times*, 9 October 1979.

Our original announcement was merely to record the event of the Moon Treaty. We, too, have reservations (see *Spaceflight*, July-August 1980). Ed.

JBIS Astronautics History

Mitchell R. Sharpe, editor of the Astronautics History issues of *JBIS*, is seeking further contributions particularly from the United Kingdom and Europe. Prospective authors are requested to write to him c/o The Alabama Space and Rocket Center, Huntsville, Alabama, USA.

SPACEFLIGHT

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 27/29 South Lambeth Road, London SW8 1SZ

Correspondence and manuscripts intended for publication should be addressed to the Editor, 27/29 South Lambeth Road, London SW8 1SZ.

Opinions in signed articles are those of contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

MEETINGS DIARY

Study Course
Theme: **ROCKET TECHNOLOGY**

A course of eight evening meetings will take place on the above topic during the 1980/81 session. Details are given on the front inside cover.

Visit
SRC APPLETON LABORATORY

Arrangements have been made for a small party of members to visit the SRC Appleton Laboratory at Ditton Park, Slough, together with a visit to their out-station, the Satellite Signal Reception Centre at Winkfield, on **10 September 1980** (all day).

Registration is necessary. Members interested in receiving further information must apply to the Executive Secretary, enclosing a reply-paid envelope, in good time.

35th ANNUAL GENERAL MEETING

The 35th Annual General Meeting of the Society will be held in the Tudor Room, Caxton Hall, Caxton Street, London S.W.1 on **18 September 1980**, 7.00 p.m.

A detailed Agenda appears in the July–August issue.

31st IAF CONGRESS

The 31st Congress of the International Astronautical Federation will be held in the Takanawa Prince Hotel, Takanawa, Minato-ku, Tokyo, Japan from **21–28 September 1980.**

FIRST NIGHT (A new type of meeting)

An opportunity for new members of the Society (and interested guests) to meet Members of the Council and Officers of the Society will occur on Wednesday, **7 October 1980**, at the Society's HQ Building, 27/29 South Lambeth Road, London, SW8 1SZ, 7.00-9.00 p.m.

It will be an informal evening which will include two talks on the History and Activities of the Society, a space film and an opportunity for a short guided tour of the Building.

New members who would like to attend are invited to apply in good time, enclosing a reply-paid envelope.

Lecture
Title: **RECENT ADVANCES IN SPACEFLIGHT**
by P. S. Clark

A review of space activities throughout the world which have taken place during the past twelve months, to be held in the Golovine Conference Room, Society HQ, 27/29 South Lambeth Road, London SW8 1SZ, on **8 October 1980**, 7–9 p.m.

Admission is by ticket only. Members wishing to attend should apply to the Executive Secretary, enclosing a reply-paid envelope.

Film Show
Theme: **HISTORY OF ASTRONAUTICS**

A number of early films on astronautics not now generally available will be screened at a meeting to be held in the Golovine Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **5 November 1980** 7-10 p.m.

The programme will include the following:
(a)-History of Rocket Development
(b)-Black Knight

Admission will be by ticket only. Members should apply in good time, enclosing a reply-paid envelope.

Visit
Institute of Astronomy

Arrangements have been made for a small party of members to visit the Institute of Astronomy at Cambridge where a tour will be made, conducted by Dr. A.C. Fabian and Mr. A.J. Whyte, on Tuesday, **18 November 1980.**

During the afternoon a trip will be undertaken to see the Radio Telescope at North Barton if sufficient personal transport by members is available. Admission, restricted to members only, will be by registration only. Applications should be sent to the Executive Secretary, enclosing a reply-paid envelope.

Lecture
Title: **SOLAR POWER SATELLITES — AN ENERGY SOURCE FOR THE FUTURE**
by R. M. B. Shelton

To be held in the Golovine Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on Wednesday **26 November 1980**, 7.00-9.00 p.m.

Admission is by ticket only. Members wishing to attend should apply in good time, enclosing a reply paid envelope.

Lecture
Title: **THE USE OF SATELLITIES IN COMMUNICATIONS SYSTEMS**
by C. R. Hume

To be held in the Golovine Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on Wednesday **3 December 1980**, 7.00 9.00 p.m.

This is the first of two talks which attempt to give an overview of Satellite-based Communications Systems. The second, scheduled for early 1981, will deal specifically with UK involvement via the Post Office.

Admission will be by ticket only. Members should apply in good time, enclosing a reply-paid envelope.

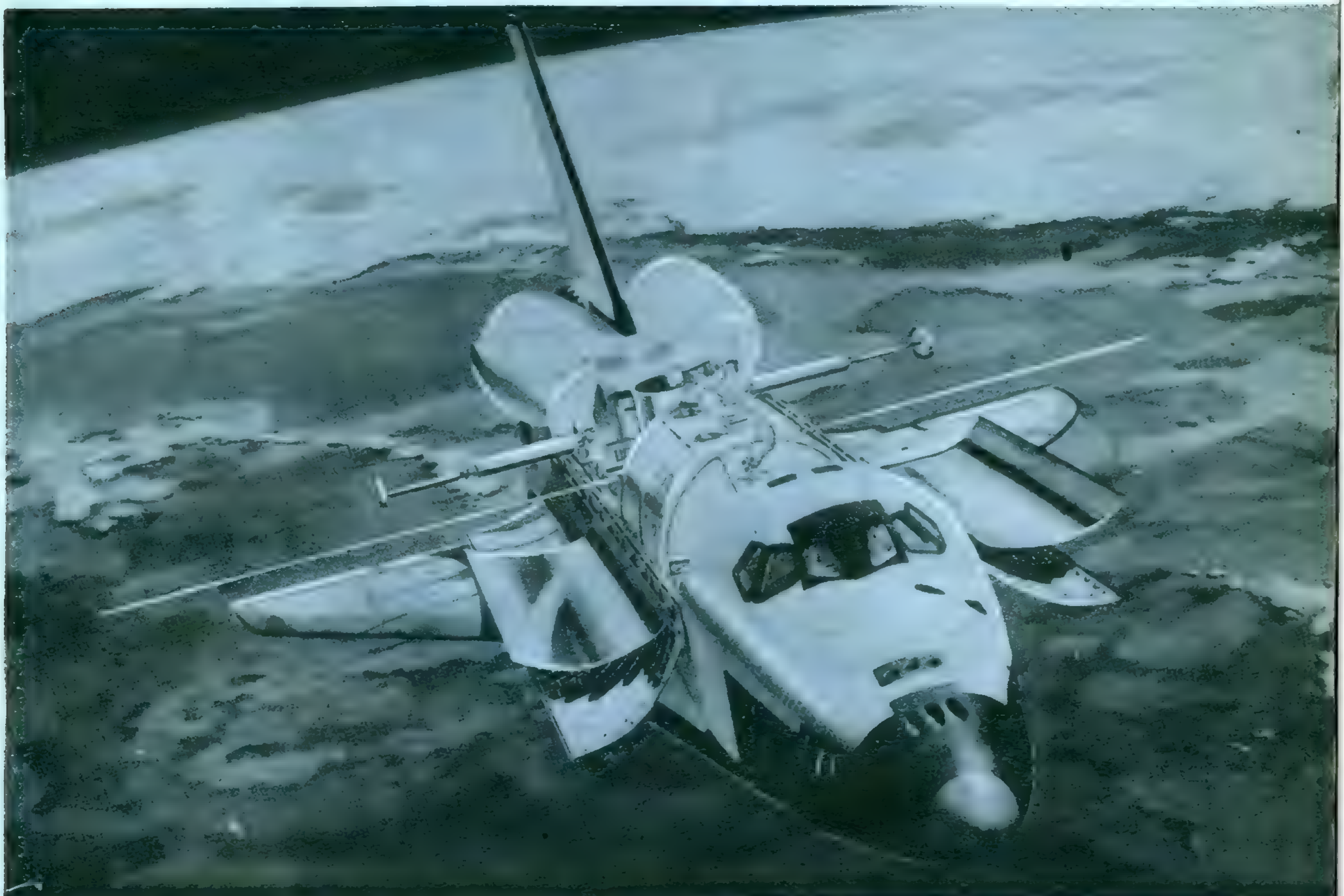
While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

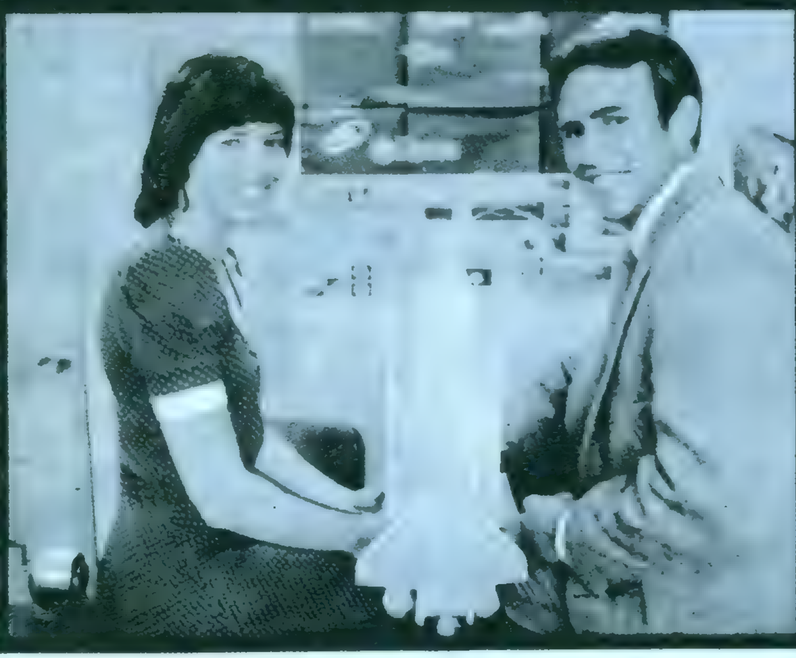
Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published for The British Interplanetary Society Ltd., (No. 402498) by Space Educational Aids Ltd., (No. 741211). Registered Office, 27/29 South Lambeth Road, London, SW8 1SZ, England.

ISSN 0038-6340

SPACEFLIGHT

88905 Космические полеты
(спейсфлайт) № Т-11-12
По подписке 1980 г.





VOLUME 22 NOS. 11-12
NOVEMBER-DECEMBER 1980

Published by
The British Interplanetary Society

THE BRITISH INTERPLANETARY SOCIETY
LIMITED *(by guarantee)*

27/29 South Lambeth Road, London SW8 1SZ

1981 SUBSCRIPTION FEES

The rates payable for the various grades of Membership for the calendar year January-December 1981 are as follows:-

RATES

Members	Sterling	US Dollars
Under the age of 18 years	£14.00	$35.00
Between 18 and 20	£16.00	$40.00
21 years of age and over	£18.00	$45.00
Associate Fellows	£20.00	$50.00
Fellows	£20.00	$50.00

Age Allowance

A deduction of £2.00 ($5.00) is allowed to members of every grade who are over the age of 65 years on 1 January 1981.

JBIS Subscription Rate

The additional subscription payable for *JBIS*, where required in addition to *Spaceflight*, is £16.00 ($40.00).

Methods of Payment

Payment should normally be made in sterling with a cheque which shows a UK address, either of the paying Bank or its Agent, where it can be presented for payment.

(b) Payments by US dollar cheques will be accepted if drawn on a Bank which gives an address in the United States or in the UK. US dollar cheques drawn elsewhere need to be increased by $10.00 to cover bank and collection charges.

(c) US dollar notes are accepted. Other currencies may also be accepted with prior agreement by the Society. Their value must be sufficient to include conversion costs into sterling.

(d) US or Canadian moner orders can only be accepted *if expressed in Sterling. Internal* money orders from these countries i.e. those expressed payable in dollars will be returned as they are not cashable in the UK.

(e) Most Canadian banks have UK branches or agents: remittances may easily be made in sterling drawn on those agents. If payment is made in Canadian dollars the current exchange rate must be used, plus the addition of 12 Canadian dollars to cover exchange and collection charges.

(f) Cheques drawn in sterling on banks in Europe (including Euro-cheques) must include £4.00 to defray bank charges and collection costs.

(g) Banks which remit directly to the Society must be instructed by members to see that the sum transmitted is *free of deductions.* (Banks frequently impose charges "in transit," so the amount actually received by the Society is insufficient to pay for the subscription thus causing much additional correspondence and trouble both to the members concerned and to the Society).

(h) Remittances from Europe can be made by GIRO: this is the easiest and cheapest method of transferring funds. Our GIRO account number is 53 330 4008.

THE SOCIETY'S LIBRARY: OUR NEED FOR BOOKS

Dear Member,

We are undertaking a substantial effort in endeavouring to build up a Specialised Space Library for the Society, though our efforts are greatly hampered by the fact that, in a period of rapidly-increasing inflation, the Society has no funds available for the purchase of books. This is why we need to rely solely on the goodwill of our members to help us acquire suitable material.

To support this Appeal, the Library Committee has asked me to write to each member of the Society who is known (or suspected) to be an Author of books of the right calibre on astronomy and space, to place our Appeal before them and seek their help, especially because the Committee particularly wishes to see that all relevant books published by members of the Society, even if they first appeared some years ago, appear on our shelves.

The Committee seek your support and hope that you will be willing and able to donate one or more copies of your works. Needless to say, if you have duplicates of any other material which you could consider parting with and donating to the Society, they would be extremely grateful for this too.

I hope you will be able to respond favourably.

L. J. CARTER,
Executive Secretary

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SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 22 NOS. 11–12 NOV.–DEC. 1980 *Published 15 October 1980*

Editor
Kenneth W. Gatland, FRAS, FBIS

CONTENTS

In view of the severe financial constraints being enforced on the Society by inflation, this is a combined issue covering the months of November–December. We expect to return to our normal publication frequency in the New Year. The January issue of "Spaceflight" will be published in the third week of December, as usual.

MILESTONES

June 1980

16 Announced in Paris that two French pilots, Lt-Col Jean-Loup Chrétien, 41, and Major Patrick Baudry, 34, have been selected for joint training with Soviet cosmonauts. One will spend a week aboard a Russian space station in 1982.

16 *Aviation Week & Space Technology* reports that a 12-person, 98-ton space station will be ready for launching in the USSR in 1985 by a rocket more powerful than Saturn 5.

25 British Aerospace Dynamics Group, Space and Communications Division, announces completion under contract to European Space Agency of a study "of the possibility of intercepting Halley's Comet by a satellite called Giotto based on the successful GEOS 1 and 2 design." Object is to pass within 621 miles (1,000 km) of the comet to obtain data on chemical composition of the coma region surrounding the nucleus and the tail; a camera will take pictures of the comet's nucleus and measurements will also be made of its magnetic field. *Subsequently, adopted by ESA as an independent project for launch, mid-1985, by uprated Ariane. Ed.*

29 Soviets launch Progress 10 unmanned cargo craft which docks automatically with Salyut 6/Soyuz 36 combination on aft airlock 1 July. Re-entered atmosphere over Pacific Ocean 19 July.

July 1980

7 NASA and ESA announce that two European scientists have entered NASA's Mission Specialist training programme at the Johnson Space Center, Houston. They are:

- Claude Nicollier, 33, Swiss, an astronomer formerly at the European Space Technology Centre (ESTEC), Noordwijk, Netherlands; and
- Wubbo Ockels, 31, Dutch, a physicist formerly with Groenigen University, Netherlands.

Both Nicollier and Ockels are now ESA employees and also Spacelab 1 Payload Specialist Candidates.

12 Mr. Michael Marshall, UK Under-Secretary for Industry, informs Parliament that Central Policy Review Staff will make a general survey of space activities to help industry take advantage of new opportunities in the field of satellites and communications. They would also consider how the various departmental interests were coordinated. "We also wish to examine the national and international opportunities and how to give Britain's industry the maximum opportunity to exploit them," he said.

12. Static test of three-engine cluster of Space Shuttle's main propulsion system, scheduled to last 542 seconds, is terminated at 106 seconds because of fire indication in the aft compartment of the Orbiter simulator. A small hole in the No 3 engine fuel preburner allowed burning gases to escape into the region above the heat shield where the engine power heads are located.

18 India launches 77 lb (35 kg) Rohini test-satellite by four-stage, solid-fuel, SLV-3 rocket of Indian design and manufacture. Launch site: Sriharikota Island, north of Madras. Orbit 180×559 miles (290×900 km) inclined at 45 deg to equator.

23 Soviets launch Soyuz 37 from Baikonur cosmodrome at 2302 hr Moscow time with cosmonauts Col Viktor Gorbatko and Col Pham Tuan (Vietnamese).

24 Soyuz 37 docks with Salyut 6/Soyuz 36 complex on aft airlock. After carrying out experiments with resident crew (Popov and Ryumin), they returned. Experiments carried out in conjunction with resident crew (Popov and Ryumin) included space medicine and biology, space technology, mapping of the surface of land and ocean, including parts of territory of Vietnam.

[Continued on page 339

COVER

SPACE SHUTTLE. If flight tests of "Columbia" take place next year as planned, 1983 could see the European Spacelab flying into orbit with Mission Specialists. Top, artist's impression shows Spacelab in the Shuttle Orbiter's cargo bay with doors opened to expose a full range of scientific experiments. *Below left*, on 29 May NASA announced the selection of 19 new astronaut candidates. The new group includes William F. Fisher, the husband of Anna Fisher, who was selected for the astronaut candidate programme in 1978. Both are doctors, sharing the specialty of emergency medicine. Now they will be sharing work as mission specialists in the space programme, although their first flights are years in the future. *Bottom right*, astronauts Bob Crippen and John Young who will be aboard "Columbia" on its maiden flight from Cape Canaveral.

Rockwell International (top); photo's NASA and Stephen Smyth.

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ARE WE ALONE AFTER ALL?

THE PENDULUM SWINGS BACK

By Robert Sheaffer

Introduction

The consensus of scientific opinion concerning the existence of extraterrestrial life has swung back and forth numerous times during recorded history. The majority view among scientists at this time holds that life is a common phenomenon in the Universe, and that there are probably at least thousands, if not millions, of other advanced civilizations in our Galaxy alone. However, the pendulum now appears to be swinging back once again, to a more skeptical position.

In remote antiquity, planets and stars were not considered to be other worlds, and hence there was no place "out there" which might be inhabited. In the sixth century BC, the influential Greek philosopher Democritus, and later Lucretius, believed the cosmos to be infinite and eternal, and hence other beings were a possibility. But Aristotle strongly disagreed, and his views prevailed for many centuries. During the Middle Ages, to speculate about the mortal inhabitants of celestial realms was to risk being burnt, both now as well as in the hereafter. One of the heresies for which Giordano Bruno was burnt at the stake in 1600 was his advocacy of the plurality of inhabited worlds. Fontenelle in the seventeenth century, and Sir William Hershel in the eighteenth, were among those who argued fervently that it is unlikely for Earth to be the only inhabited planet in the cosmos.

Then for much of the nineteenth century and early twentieth, the pendulum swung back to disbelief (although Percivall Lowell had a good many people convinced that intelligent creatures existed in our own Solar System, on Mars). The Sun's planetary system was held to be the result of a rare chance encounter with a passing star, perhaps the only one of its kind in the Galaxy. But as the twentieth century advanced, the pendulum swung back towards belief in the plurality of inhabited worlds, that life is a common phenomenon in the Universe. The idea of a Search for Extraterrestrial Intelligence (SETI) became scientifically respectable with Cocconi and Morrison's classic paper in *Nature* in 1959, and Dr. Frank Drake's *Project Ozma* in 1960. The best-known proponent of the pro-SETI view has been the astronomer Carl Sagan. Today the pro-SETI viewpoint is espoused by the great majority of astronomers and other scientists.

The Pendulum Swings

But within these past five years, the pendulum has once again begun to swing back slowly but dramatically to a position more skeptical of the prospects for SETI, and to a decreased estimate of the likelihood of life ever developing. One of the most dramatic developments has been the defection from the staunch pro-SETI ranks by some of those who have in recent years been ardent SETI advocates and even SETI experimenters, including Sebastian Von Hoërner, Ronald Bracewell, I. S. Shklovskii, Benjamin Zuckerman, Patrick Palmer, and Gerrit L. Verschuur.

The SETI skeptics' high-water mark to date has been the symposium held at the University of Maryland in College Park on 2-3 November 1979. Its organizers were astronomers Michael Hart of Trinity University, Benjamin Zuckerman of the University of Maryland, and Michael Papagiannis of Boston University. The "by-invitation-only" conference was titled "Where Are They? A Symposium on the Implications of our Failure to Observe Extraterrestrials". The title of the conference is especially appropriate, as it makes clear two fundamental areas of agreement among the participants: one, that evidence of extraterrestrial activity has *not* been observed by us; and two, that certain facts can be deduced from the *absence* of extraterrestrials on Earth.

One U.S. billion = 1,000 million, applies throughout this article.

Is the search for extra-terrestrial intelligence fruitless after all? This concept of an "Unmanned Extra-terrestrial Space Vehicle" is by Donald P. Simpson (Simpson: Research and Design).

National Air and Space Museum, Smithsonian Institution

Where Are the "Space Arks"?

To briefly summarize the major line of reasoning that kept surfacing throughout the conference: There are no fundamental obstacles to the colonization of space, and there is no plausible reason that a civilization only a little more advanced than ours could not eventually colonize the entire galaxy in giant space-arks. The shadow of Gerard O'Neill's space colonies loomed large across the conference. A general tendency of life, it was repeatedly noted, is to spread outward to fill every niche suitable to it. With the advent of the idea of space colonies, built in space from the raw materials found there, *space itself has now become* a suitable environment for an intelligent species. There are many stars in our galaxy far older than the Sun, and if life is truly abundant, as the SETI proponents claim, there should be civilizations millions, if not billions, of years older than ourselves. The pro-SETI people claim that such civilizations are indeed out there, but because of the extreme difficulty of interstellar travel, they expend their energy talking with other members of the "Galactic Club," a sort of cosmic ham radio linkup. The anti-ETI people, however, argue that if such civilizations have existed for billions* of years, at least one of them by now would have spread its space colonies into every nook and cranny of the Galaxy. As this had demonstrably not happened, we earthlings are probably the first space-faring civilization to evolve in the Galaxy.

In an ironic twist, a great many of the arguments of the pro-SETI people are being turned around by the SETI skeptics to their own advantage. "There are multitudinous civilizations in our Galaxy far older and millions of years more technologically advanced than ourselves." Very well, then explain why not one of them has developed and spread throughout the Galaxy the very same space colonies that a backward civilization like us currently has on the drawing board? "The Earth may have been visited a thousand times in its history by alien races." Very well, then why did not one of them establish a colony here, whose inhabitants would remain as rulers of our planet even today, by virtue of a vastly superior technology? (It is absurd to argue that we are them, that the human race is not biologically related to horses, crabgrass, and every other life form native to Earth). "Contact with a more advanced civilization overwhelms, and even destroys, the less advanced

one". Very well, why have we not thus been overwhelmed and destroyed? It must be because no civilization more advanced than we exists, *since even we will reach the stars in just a few thousand years*, a mere moment in the cosmic time frame.

It can be argued that, in an environment where life is abundant, nothing is more rare than an unclaimed resource. No item of food, left on the ground outdoors on a warm summer day, need wait long until countless insects, both flying and crawling, turn up to claim it. The rich farmland of the American midwest – another unclaimed resource – was fully claimed within two generations of it becoming available for settlement. Are we to believe that, in a galaxy teeming with advanced civilizations, our own rich, lush, warm Earth would remain an unclaimed resource over geologic epochs, hundreds of even thousands of millions of years? The most straightforward explanation for that astonishing lack of interest seems to be *that there is no one out there to claim it*.

Many have assumed that the time frame required for the colonization of the Galaxy would be impossibly large. But a little reflection shows that this is not so. The radius of our Galaxy is somewhat less than 50,000 light years. Assume the existence of a single, space-colonizing civilization near the center of the Galaxy. Let us assume that their giant, lumbering space-arks, supporting many thousands of space colonists, travel at only 1 per cent of the speed of light. Let us further assume that every time they travel 100 light years, they stop at a favourable solar system, spend a thousand years crunching up asteroids to build more space colonies, and then some of them remain behind as permanent residents, while the more adventuresome colonies press on to conquer other stellar systems in the same manner. Such a wave of colonization would proceed outward at an average rate of 0.91 light years per century. At that rate, it would require roughly 5½ million years to totally saturate the galaxy with O'Neill-type galaxies – *just an instant in the history of our Galaxy*. And this assumed just a *single* highly-advanced civilization in our Galaxy – many SETI advocates hypothesise a million or more! And *not one* of them is clever enough to do this?

Mathematical Models

Astronomer Eric M. Jones of the Los Alamos Scientific Laboratory presented the Maryland Conference with his more sophisticated mathematical model of the spread of colonization across the Galaxy (the above model is admittedly an oversimplification, but it closely matches Dr. Jones' figures). He found that, making certain optimistic but nonetheless realistic assumptions, most of the solar systems in our Galaxy would be populated with space colonists in just six million years. The galaxy is at least 2,000 times older than that. Even granting the validity of certain objections to his calculations by Carl Sagan and others, the time frame expands to just 625 million years, less time than the SETI advocates believe separates us from the most advanced civilizations in the Galaxy. Jones suggests that the smaller time estimate is probably a more realistic one. Regardless of which figure is the more accurate, *where are they?*

Life – a Ruthless Influence?

Radio astronomer Ronald H. Bracewell of Stanford University, famous as the popularizer of the idea of the "Galactic Club", is now firmly in the camp of the SETI skeptics. Bracewell delivered a paper to the Maryland Conference suggesting the "Preemption of the Galaxy by the first advanced civilization". His argument might be paraphrased, "the early bird gets *all* the worms". Bracewell observes that none of the several hominid species which were related to man but were not our direct ancestors has managed to survive. It appears as if the most advanced hominids – our ancestors – totally exterminated their less intelligent, and less technological, cousins. History is replete with examples of a more advanced civilization overwhelming, and all but obliterating, a less advanced one. Would not the same thing be likely to occur on a galactic scale? "No doubt the diffusion of human control into interplanetary space will proceed in the future", Bracewell argues. "Whether man's destiny is to penetrate the Galaxy depends on diffusion time versus evolution time. Estimates do not eliminate the prospect that the first galactic species whose biological evolution brings technology within reach may spread over its planet, through its planetary system, and continue on into the Galaxy to preempt or incorporate alien culture should such be encountered."

Sebastian Von Hoërner of the National Radio Astronomy Observatory, a longtime SETI theorist and advocate, is likewise gravitating into the skeptics' camp. Von Hoërner told the Maryland conference that "our own present activity is still mostly self-destructive, with a world-wide arms race of 400 billion dollars per year, 100 times the budget of NASA, or 400 times that of NSF (National Science Foundation). We may either blow up, or redirect this enormous work force, hopefully to exploration and exploitation of the resources of our Solar

The three co-organizers of the "Where Are They?" Conference, shown during a break in the proceedings. *From left:* Michael Pappagiannis, Boston University; Benjamin Zuckerman, University of Maryland, and Michael Hart, Trinity University (Texas).

Robert Sheaffer

System, and to large SETI projects". He continues, "large self-sustaining and profitable colonies throughout our Solar System can be made even with our beginner's technology (and much less money than the arms race). Later these colonies could send thousands of people in large "mobile homes" on interstellar trips lasting several generations, colonizing planets of other stars ... a colonization wave could stepwise cover the entire Galaxy within some ten million years. Such waves could have been started by any one of the billions of early civilizations. In general, life shows the tendency to fill every possible niche, from deserts to polar regions ... we then have the great puzzle that the whole Galaxy should be teeming with life, obvious in many ways, and the Earth should have been colonized long ago, whereas we have not yet seen any evidence of any extraterrestrials. Many reasons against colonizing can be mentioned: self destruction of technologies, biological degentation, stagnation by over-specialization ... all of these reasons may hold in some cases, maybe in most cases, but hardly with no exception at all in a billion ... A possible conclusion then is that we are actually alone, by some reason not yet understood." Von Hoërner concludes that "the great puzzle is still unsolved."

Other speakers filled in certain "reason(s) not yet understood" why we may in fact be alone in the Galaxy. Shiv S. Kumar of the University of Virginia explained that as "single stars appear to be quite rare, the existence of planetary systems similar to our own cannot be a universal phenomenon. Consequently, the existence of life around other stars in our Galaxy may be a much rarer event than generally believed". He adds, "I continue to be opposed to expensive programmes to search for 'intelligent' life around other stars." Virginia Trimble of the Universities of Maryland and California noted that while relatively few stars have as high a proportion of heavy elements as the Sun, enabling Earth-like planets to form, there are a significant number of stars a billion years older than the Sun with enough heavy elements to condense "earths" of their own. Yet we see no evidence of their space colonies here. Conference co-organizer Michael D. Papagiannis of Boston University observed, "given the delicate balance that exists between run-away glaciation and a run-away greenhouse effect, planets that can maintain a liquid water environment for billions of years and hence where life finally reaches the technological state could very well represent a truly rare occurrence."

Evolution of Life-bearing Planets

The conventional wisdom in present-day astronomy has it that stellar systems in the process of formation must lose some of their angular momentum as they contract, to either a stellar companion, or to a system of planets, to avoid flying apart. Hence *all* stars which are not part of multiple stellar systems must have planets. J. Patrick Harrington of the University of Maryland challenged this rosy view. "The low rotational velocity of lower main sequence stars (like the Sun) need not imply that angular momentum has gone into the formation of planets." Some angular momentum could be lost to "stellar winds" (analogous to our Sun's solar wind), or to the formation of tiny "planetesmals" such as meteoroids. The Sun's rotation seems to be anomalously slow for a star of its age, Harrington noted. Perhaps this is because the Sun is one of the *few* stars that actually does have planets!

Freeman Dyson, of the Institute for Advanced Studies at Princeton, is famous for proposing that super-advanced civilizations might dismantle entire planets and build a "Dyson sphere", a gargantuan beach ball, around their solar system. Professor Dyson addressed the conference on some highly-speculative means that an absurdly-advanced technology might utilize for interstellar colonization, including magnetic accelerators nearly a light year in length, and using the *same* Earth-based laser to both accelerate a vehicle to its stellar destination, and to slow it down upon its arrival. (The trick is to go *past* your destination, and then use the extremely weak magnetic field of the Galaxy to leisurely turn your course 180° in six centuries or so, heading back toward Earth, so that the laser will this time slow you down). Dyson's ideas have always been wildly unconventional! Dyson presented rough estimates of the performances and size of "various vehicle and propulsion systems that may be appropriate for interstellar missions. These estimates lead to the conclusion that there is no lack of suitable systems available to any society which wishes to colonize the Galaxy."

"Occam's Razor"

There are, of course, those who claim that extraterrestrials *are* here, and that we need look no farther than UFO reports to see evidence of their presence. I presented a paper at the Maryland conference to challenge this view. "Occam's Razor" requires that extraordinary hypotheses not be adopted unless no conceivable prosaic explanation will suffice", I noted, explaining a cornerstone of the scientific method. But "none of the presently-categorized 'unknown' cases provides indisputable evidence to rule out all prosaic factors." Several examples were given of "classic" supposedly unexplained Close Encounter UFO cases which are seen, upon critical examination, to be without merit. "Over the past thirty years many short-lived or rare phenomena have successfully been photographed ... yet UFOs seem to have an utterly infallible ability to avoid unambiguous detection." I conclude that "The 'null hypothesis' has not been excluded", and hence Occam's Razor dictates that we should go no farther.

James Oberg of NASA's Johnson Space Center in Houston, a well-known writer on the space sciences, presented a paper on Terraforming: making over other planets in the Earth's own image (certain to bring howls of protest from the Sierra Club and the anti-growth intellectualoids!) He notes that "the feasibility of terraforming underscores the remarkable observation that it has *not* happened, at least locally." Oberg goes on to note that "planetary engineering is only the forerunner of our stellar engineering, and nebular engineering and galactic engineering. ... artificial activities whose presence should be obvious at least within a galaxy and probably across intergalactic gulfs as well. Our failure to recognize such activities suggests the exact converse of one of Sherlock Holme's aphorisms, to wit: 'Absence of evidence *is* evidence of absence'.

Origin of Earth-life

Taking a more pro-ETI stand was the eminent biochemist Cyril Ponnamperuma of the University of Maryland, who described his experiments in synthesising amino acids in "primordial soup", a vile mixture believed to closely replicate conditions on the primordial Earth. "Life is considered to be the inevitable consequence of the evolutionary process in the Universe", he stated. However, other conference participants challenged his optimism, on the grounds that the organic molecules he obtained fall many orders of magnitude short of the complexity of RNA, DNA, and the other true building blocks of life (although I suspect that if we gave Ponnamperuma a few hundred million years, he might be able to do a little better).

Other conference participants zeroed in on the question of the development of life itself as the weak link in the ETI chain. Edward Argyle of the National Research Council of Canada noted that while the emergence of life seems to be a natural development in the evolution of a solar system, "our failure to discover any evidence of extraterrestrials suggests that at least one of these steps was highly contingent. The intractability of the problem of the origin of life may be an indication that the origin was fortuitous and improbable". Hubert P. Yockey of the Army Aberdeen Proving Ground in Maryland examined the question of the emergence of life from the perspective of entropy and information theory. He calculates the absurdly low probability of complex organic molecules

arising, purely by chance, in Darwin's "warm little pond", and concludes that "a belief that true proteins of the same information content as cytachrome C appeared frequently in the primeval soup is based on religious faith not on scientific evidence."

Life on a Knife-edge

What was perhaps the most provocative paper of all was saved for last, that of the Maryland conference's principal organizer, Michael H. Hart of Trinity University. Hart started with the famous Drake equation for estimating the number of independent technological civilizations: the number of stars in the Galaxy times the fraction having planets on which life has arisen, etc. However, the numbers he indicated must be used are clearly among the most pessimistic that have been proposed. Computer simulations of the evolution of planetary atmospheres were made for planets of differing masses, differing orbital sizes, and differing solar masses. His study revealed that "only for a very small range of these parameters will the surface temperature of the planet remain continuously, for billions of years, in a range which permits H_2O to exist in the liquid phase." Hart estimates that if the Earth's mean distance from the Sun, 92,956,000 miles, were reduced to just 88,300,000, a runaway greenhouse effect would have already caused the Earth to have become a Venus-like hell. On the other hand, runaway glaciation would have frozen *all* of the water on our planet (as on Mars) if that distance were increased to just 93,885,000 miles, a mere one per cent. (Indeed, a glance at Earth's previous ice ages serves to remind us how close to this doom we actually came!).

While this is discouraging enough, Hart saved the worst for last: his estimate of the probability of life originating, even where conditions are totally favourable. Hart asserts that "the unlikelihood, even under ideal circumstances, of pre-biotic processes lining up 600 or more nucleotides in the right *order* suggests that the fraction of planets developing life is much less than 10^{-30}. Hence (the average number of life-bearing planets in any Galaxy) is 1. This agrees with and explains the common observation that the Earth "has not been colonized by extraterrestrials." By making what he considers to be absurdly favourable assumptions concerning the development of life by random processes from non-living matter, rhetorically bending over backwards to concede points to his critics, Hart estimates that the probability of life arising even under ideal circumstances is just 1 in 10^{37} (1 followed by 37 zeroes). Since he estimates that there are 10^{6} favourable planets in a typical Galaxy, our Galaxy is a true cosmic rarity, representing the *one* galaxy in 10^{31} that contains a planet with life of *any* kind. And that, Hart insists, is an extremely *optimistic* estimate! If Hart is correct, we are certainly the sole inhabitants of our own galaxy, and for all practical purposes, alone in the Universe.

Alternative Life-Forms

Not *all* scientists at the conference were totally pessimistic about the prospects for eventually encountering ETI (and few of the pessimists were quite as pessimistic as Hart). Ponnamperuma has not changed his view that the development of life, in favourable circumstances, is not particularly rare. J. Richard Gott III of Princeton University delivered a moderate pro-SETI paper. His argument is that, since modern cosmology seems to suggest an "infinite negatively curved space with an infinite number of galaxies, any finite probability for forming life will lead to an infinite number of civilizations," even if there are far fewer civilizations than there are galaxies. He suggests a rather complex means of deriving a universal "natural" wavelength, and a universal standard of rest, from Planck's Constant, a physical parameter as fundamental as the speed of light, "e", the base of the natural logarithms (like pi, a truly universal number), and the 2.7°K cosmic blackbody radiation, the radio remnant of the Big Bang. This precise wavelength would enable civilizations to transmit and detect extremely narrow bandwidth signals across intergalactic distances.

Gerald Feinberg of Columbia University and Robert Shapiro of New York University gave a joint talk on the possible existence of "alternate" forms of life radically different from anything in our experience. Beginning with a set of generalized requirements for life: "a flow of free energy, a system of matter capable of interacting with the energy and using it to become ordered, and enough time to build up the complexity of order that is associated with life," they find that it opens up possibilities for "life" to develop out of gaseous nebulae, from planetary crusts, oceans, and atmospheres, and even below the surfaces of neutron stars! "It is possible that life is very prevalent throughout the Universe", they suggest – but *not* life as we think of it on Earth. Such life, one might presume, could never leave its peculiar niche and colonize the Galaxy (or could it???).

Broad Concensus

Nonetheless, it *is* fair to say that a broad consensus existed among nearly all the participants at the "Where Are They?" Conference. In general, it was agreed that (1), extraterrestrials apparently have *not* been to the vicinity of Earth (not one of the speakers was willing to grant any factual basis to the claim that UFO reports suggest the activities of ETI); (2), that interstellar colonization is possible, and indeed even likely; (3), that the absence of extraterrestrials on Earth, and of colonization of our Solar System, indicates that intelligent life is far less common than had been previously thought. It is possible, perhaps even likely, that we are alone in the Galaxy. History alone will tell if this view is correct.

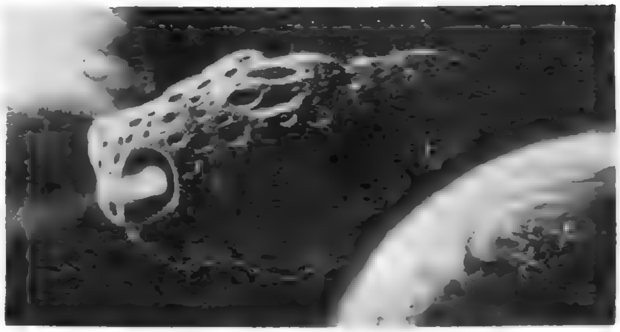
It can be argued that the reason that the conference concluded what it did is that this is the first major SETI "brainstorming" conference to take place since the idea of O'Neill's Space Colonies became commonplace. Those Space Colonies haunted the Maryland Conference, hovering nearby always just out of sight; it was O'Neill who unwittingly killed the idea of a Galaxy filled with super-advanced civilizations, each impotently bound to to its own planetary system for eons by the speed of light, each content to discourse Platonically over that magnificent Galactic Party Line. It was O'Neill who opened up the stars. As one astronomer said to me in private conversation, "for me, the turning point on this question came when I realized that an interstellar voyage need not be made in a single lifetime. That changed the entire perspective." Colonization of other solar systems became possible, and eventually the entire galaxy must be settled. This has not happened – at least, not yet. Another astronomer remarked to me over lunch: "when I first became interested in this question, I was a believer in Saganism". It would indeed be ironic if history were to record that space advocate O'Neill had unwittingly unleashed the avalanche that buried belief in extraterrestrial intelligent life.

But just as there is a ray of hope in Sagan's doctrines, we can find optimism in Hart's doctrines as well. If Hart is right, the entire Galaxy belongs to the first intelligent civilization to come along to claim it. That is us. There are no "limits to growth": the entire Galaxy – perhaps ultimately whole clusters of galaxies – belong to us. The destiny of the human race would be to spread *life*, that rarest and most wonderful of cosmic accidents, out to the stars. While Sagan believes that our Galaxy is now teeming with life, Hart believes that it some day will be, and that it is to be our descendants who will carry the torch.

NEXT MONTH we begin a new series of articles by Dr. J. E. Davies commemorating the Voyager missions to Jupiter and Saturn. Nicholas Johnson compares the "A" and "B" launch pads for Soyuz spacecraft at the Baikonur cosmodrome, and Dave Dooling reviews "Experiments of Opportunity for the Shuttle."

THE SEARCH FOR INTELLIGENCE

By E. J. Coffey



An "Asteroid Ark".

Painting copyright David A. Hardy, from "The New Challenge of the Stars", Mitchell Beazley (1978).

Introduction

Man is indubitably a unique animal: not only is he aware of his own existence but he can also ask how he originated and, looking across the vast inhospitable expanse of the cosmos, wonder if he is alone. Only a unique combination of sensory and physical capabilities have endowed him with those special gifts to which the range of his intellectual and technological achievements testify. Many philosophers and scientists have believed that man is incomparably unique, that an evolutionary "quantum jump" has characterized his development. In fact, the available evidence just does not substantiate such a belief. Ironically, at the very time that interest in the possibility of extraterrestrial intelligence is at its highest no general theory of intelligence exists. The views that do exist are usually confused and contradictory, and of limited applicability. Fortunately, a relatively new theory - the perceptual theory of intelligence [1, 2] - permits understanding of the nature of intelligence, as well as creativity, the role of language, and the scope and ultimate limitations on human comprehension of the Universe.

The Perceptual Theory

Dissatisfaction with today's prevailing attitudes towards intelligence partly arose from the realization that other higher mammals, especially apes and dolphins, can invent, learn language (only apes so far), and solve problems in an analogous fashion to humans. This suggests that the higher mammals, at the very least, can think; that is, they can both form and manipulate concepts. It also suggests that the ability to conceptualize precedes the acquisition of language: linguistic signs simply label such pre-established concepts. The existence of such abilities only truly make sense if they are the product of similar cognitive processes. Man's ancient dream of communing with the animals is much closer than most of us have ever dreamed because of such commonalities, despite the often apparently enormous differences.

Support for the validity of the perceptual theory comes from Arthur Koestler's systematic study of creative thought [3]. It reveals that thinking is characterized by both irrationality and spontaneity and is thus not a logical process (placing even greater strictures upon any computer analogy for thinking). It also stresses the importance of a survey made in 1945 of the methods of thinking of American mathematicians (including Einstein). The survey concluded that the decisive phase of the creative act primarily relied upon the use of imagery (generally visual though it could also belong to any other perceptual modality) and only secondarily upon language such as Einstein affirmed to serve only for purposes of communication. It can be shown that these "perceptual images" are equivalent to the terms "perceptual concepts" or "perceptual hypotheses". Obviously then language cannot be the medium of thinking as has been widely supposed for most of recorded history.

Human Ascendency

A major factor responsible for hominid evolution seems to have been propitious environmental conditions such as the worldwide climatic changes which promoted the spread of savannah. One modest behavioural change - the liberation of the hands from a locomotor function - was of crucial importance for it paved the way for man's eventual domination of the world especially as the result of two major inventions: language and technology [4]. Very strong selection pressures must have been operative upon the ancestral hominid as it increasingly encroached upon the savannahal including such diverse factors as range of visibility, tool-use and tool-making, anti-predator behaviour (surveillance, intimidating displays, weapon use) and object carrying (food, water, babies, tools, weapons) ultimately resulting in upright posture and habitual bipedal walking. Hands frees from a locomotor function permit technology via the manipulation and manufacture of tools, as well as enabling gestures without which, contrary to expectation, language would have been impossible. A mouth freed from procuring food, carrying objects, and threatening or exerting aggression is likely to be capable of producing the complex vocalization of speech, the dominant form of language today. Competent, manipulative hands and a sophisticated language are essential faculties for a cultural animal: both combining to permit the intentional shaping of the world to chosen patterns. These two faculties are central to man's extreme adaptability: why man is not adapted to any particular ecological niche; why man is now both psychologically and technologically capable of coping with any challenge the world has to offer.

It is widely and almost unquestioningly believed that man is "more" intelligent than other animals or even that individual humans differ in "amount" of intelligence. That such a misleading notion has arisen is simply a by-product of the general lack of a theory of intelligence, the only readily available analogy being that of "size". The reason for this criticism is that intelligence is the quality of a process, namely, the capacity to understand. Consequently it is possible to reconcile the capabilities of the higher mammals - invention, humanlike problem-solving, language acquisition - with the corresponding abilities of humans. This makes sense, biologically and anthropologically, for it means that intelligence must have been the common patrimony of the ancestral hominid and the apes from which it diverged some 6 to 10 million years ago. The primary support for this comes from consideration of a biological effect called neoteny [5, 6, 7]. Neoteny or the retention of fetal or juvenile characteristics into later stages of an organism's development has resulted, in the case of the higher primates and especially man, in prolonged prematurity and thus increased possibilities of prolonged learning. Man is primarily a learner and this is crucial to any understanding of man's ascendency and his adaptability. Jerison [8] has argued that the great flexibility of language differentiates it from simple communication systems, which are essentially "prewired", and postulated that language developed primarily for the evocation of perceptual or mental imagery, the role of language in communication developing secondarily. Furthermore, the late scholar and linguist Ronald Englefield [9] has shown how language must have developed via the sequence self-explanatory gesture-language, conventional gestural language, to oral language, starting with an animal with a similar

rudimentary inventive ability and intellect as apes generally demonstrate in the wild. Language does not provide us with a "universal computational ability" as is generally supposed by those who favour the computer metaphor. Briefly, language serves a labelling, indexing and mnemonic function as well as aiding the evocation of perceptual imagery. Consequently it is an enormous aid to thinking and imagination though, again, it must be stressed that language is not the medium in which thinking occurs.

The Prospects for SETI

At least since the Greenbank conference in 1961 [10] it has generally been argued that because of the enormous survival value of intelligence its appearance on an inhabited planet is almost inevitable. Usually, the phenomenon of parallel evolution is adduced in its favour. Although it is true that intelligence does confer adaptable behaviour on other animals this is as nothing compared to the potentialities of human behaviour. As a result arguments based upon "parallel evolution" are extremely misleading. Despite the commonalities between man and other animals, far more than usually thought, man's emergence, in terms of the history of this planet, has been a totally unprecedented event, the product of propitious environmental conditions and a unique concurrence of sensory and physical attributes, together with the inestimable contributions from neoteny, prolonged learning, language, and technology. What this suggests is that SETI (the search for extraterrestrial intelligence) is not concerned with the likelihood of intelligence arising on another planet for, short of actually visiting it, this would remain undetectable. SETI is concerned with the probability of the emergence of intelligent, technologically-oriented, and communicative creatures. This is because, in reality, SETI is essentially a philosophical venture and, perhaps, the most important man has ever contemplated. It broaches upon those ultimate questions which it is in man's nature to ask, such as the nature of the cosmos, and man's place in it, and the mystery of one's own existence. We want to know if, somewhere in this vast Universe, beings comparable to ourselves exist who, likewise, wonder and speculate upon imponderables.

The odds against the success of SETI are truly stupendous not only because of the size of the Universe but because the more we learn the more we realize how little we really understand. The emergence of a creature like man was by no means inevitable. For example, Jerison has argued that mammalian intelligence only arose as a side-effect of the solution of a neural packaging problem by the earliest mammals some 200 millions years ago. If this is true of the Earth how much more difficult is it to consider what has happened upon another world about which we know absolutely nothing. In addition, the major stimulus to the evolution of the higher vertebrates has been the extent and intensity of plate tectonic-induced changes whether climatic, oceanic, environmental, or involving the unification or splitting of the continents (thereby affecting the distribution, proliferation, stabilization or extinction of different groups of organisms). It can thus be seen that the prospects for SETI are extremely slight though this does not mean that the development of functional equivalents of man is impossible. We really just do not know. Because of this level of ignorance it is very difficult to justify (logically that is) an extensive SETI programme at the present time. It would be far more reasonable to treat SETI as a long-term project subsidiary to normal astronomical studies. For many these conclusions may sound harsh but they are the best that can be expected under our current limited knowledge.

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MILESTONES/*Continued from page 333*]

31 NASA confirms a decision made earlier this year to schedule the first Space Shuttle launch in March 1981. The announcement follows "an intensive review of the Space Shuttle programme carried out over the past several weeks." Dr. Robert A. Frosch, NASA Administrator, said the decision "to continue the drive toward a March launch was made even though the Shuttle programme received a potentially serious setback on 30 July when fire damaged a Shuttle engine during a test in Mississippi".

31 Re-entry module of Soyuz 36 soft-lands with cosmonauts Gorbatko and Tuan at 1815 hr Moscow time about 112 miles (180 km) SE of Dzhezkazgan.

August 1980

8 NASA announces that flight controllers have shut off the radio transmitter of Viking Orbiter 1 which has used up altitude control gas and can no longer point its antenna at the Earth, its solar panels at the Sun, and instruments at Mars. Only Viking now operating is the Viking 1 Lander which could continue to send weekly weather reports for the next 10 years.

29 Joint NASA/American Society of Engineering Education 10-week summer study of possible "Space Missions for the Next 25 Years" ends at University of Santa Clara, California. Discussions centred on: An orbiting space factory, a self-directed deep-space exploration robot, a fully automated Earth resources and environment monitor and "a lunar base that could grow through self-replication of many of its elements." Robotics, artificial intelligence, automation and remotely operated systems are vital to the future of these missions.

29 Announced that British Government is planning a new series of defence communications satellites to replace Skynet II in a 12-year period beginning 1983. Marconi Space and Defence Systems are making preliminary studies.

September 1980

5 NASA announces the discovery of a 16th moon of Jupiter in photographs taken by Voyagers 1 and 2. It has a diameter of about 25 miles (40 km) and orbits Jupiter once every 7 hr 4 min 30 sec about 35,000 miles (56,330 km) from the cloud tops. The third new Jovian satellite detected in this way, it is tentatively identified as 1979 J3.

INDEX VOLUME 22

As this issue of SPACEFLIGHT goes to press earlier than usual, we are making arrangements to publish the Index for Volume 22 in an early issue next year.

JBIS journal of the british interplanetary society

The 12 monthly issues of *JBIS* for 1980 provide an excellent coverage of technical space topics, with special issues on: *SPACE SCIENCE AND EDUCATION; IMAGE PROCESSING; SPACE HISTORY* and *INTERSTELLAR STUDIES.*

The contents of the issues which have been published since the last list (*Spaceflight*, March 1979) are given below.

Members can obtain these twelve 1980 issues for £13.00 ($29.00) postage inclusive. The five *INTERSTELLAR STUDIES* issues, which include a completely revised and updated *Bibliography of Interstellar Travel and Communication* can be obtained separately for £7.00 ($16.00) post free.

Back issues or sets of *JBIS* for 1979 and 1978 are also available, with incomplete sets for 1977. Further details are available on request.

Orders and remittances to be sent to:
Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ, England.

SALYUT 6 MISSION REPORT* – PART 4

By Neville Kidger

Continued from April Issue, page 154

The Protons Readapt
Soviet physicians were delighted by the manner and speed of the Protons' readaptation to Earth gravity. The first medical check-up, 30 minutes after landing, showed them to be in better all round health than the Photons after allowance had been made for their general orthostatic instability, which manifested itself as dizziness, pallor and slight nausea upon standing. For the first time cosmonauts returning from space experienced slight difficulty in speaking. Lyakhov was the worst affected of the two.

The acute conditions of readaptation lasted just 3 days, only half as long as the Photons. Soviet physicians tried several new methods to overcome these acute sensations with the Protons which included allowing them to swim for short periods in the indoor pool of the hotel Kosmonavt at Leninsk. It was hoped that this would enable the crew to "relive" the condition of weightlessness. As a precaution nets were strung across the bottom of the pool. Muscle-reconstituting massage was tried, as were short spells in the Finnish steam baths. On their first try in these activities the cosmonauts were able to stand only 3 minutes of exposure.

Although Ryumin said that he felt well enough to perform gymnastic exercises on the first day at the cosmodrome the request was vetoed until the third day when they were scheduled. The first series of exercises included 10 minutes of jogging between 300 to 1,000 steps increasing by the week's end to 10,000 steps. The cosmonauts enjoyed riding an ergometer to test their vestibular apparatus. Ryumin especially enjoyed playing tennis with Dr. Robert Dyakonov although 175 days in space had not helped his game at all – Dyakonov still won every match!

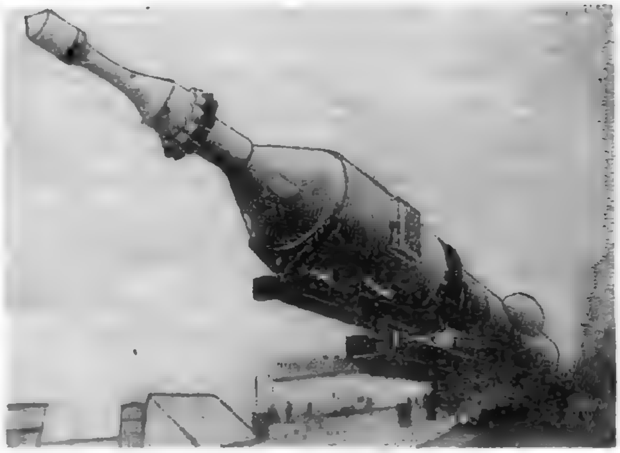
For their stay at Baikonur the cosmonauts adhered to the 0800 to 2300 hrs (Moscow Time) timetable they had followed in space even though the location was two hours ahead of MT. The men slept soundly, without recalling any dreams, but complained of discomfort because their light blankets felt heavy and their soft beds hard as bare boards. They usually awoke feeling fit and fresh. Small meals eaten regularly were the rule after Ivanchenkov had warned that large meals lay heavily on the stomach.

After about one week at the hotel Lyakhov and Ryumin were allowed time to relax from their rigorous medical tests. They were photographed strolling around the hotel grounds, eating slices of melon, planting a tree in cosmonaut's Alley and riding bicycles. The 30° plus noontime temperature and exposure to unfiltered solar UV radiation caused their faces to redden noticeably.

Part of their time between leaving Baikonur on 9 September and stays at camps in the Crimea with their families was taken up with a visit to Moscow where in meetings with the press the men looked healthy and happy.

Press Conferences
During their discussions of the flight the cosmonauts noted that work with some of Salyut's equipment, notably the BST 1M, required three men for total success. In a discussion on their interrelationships they agreed that although there had been, inevitably, disagreements between them they – as would all normal individuals – quickly resolved these problems and achieved uninimity. This was vital over such a long flight. It would become even more important still on longer stays in space.

Commenting on this Konstantin Feoktistov noted that specialists had yet to determine the optimal length of a space flight from the standpoint of scientific return. When asked the date of the Soviet Union's first attempt at a year long mission Feoktistov said that no date could be announced noting that the reason was not secrecy but because of the probability of problems restricting the achievement of longer stays as flight durations increased.



A recent picture of an A-2 rocket at the Baikonur cosmodrome ready to be elevated into the vertical launch position. Within the nose shroud is a Soyuz spacecraft.

Novosti Press Agency

Writing in *Aviatsiya i Kosmanavtika* cosmonaut chief Vladimir Shatalov said that the Salyut flights of 1977-79 posed problems specialists were struggling to overcome and which worried all those involved with the project. The amount of data the cosmonauts collected was swamping the specialists studying it. Shatalov said that one month of work aboard Salyut yielded data that would take two years to analyse. To think of orbiting larger space stations, Shatalov said, could be self defeating. Western observers expect the next civilian Salyut to be slightly larger than Salyut 6 and plans have been advanced in the USSR calling for two Salyuts to be docked together possibly within the next five years. For the expansion of Salyut activities to be a success more versatility is required in the types and numbers of crewmen flown to the station. With this in mind the Soviet Union has developed a new version of Soyuz for future Salyut flights.

Soyuz – T Features
By 29 November 1979 Salyut 6 had sunk to an orbit of 352×372 km altitude; period 91.5 minutes, approaching an ideal launch/landing window opportunity between about December 18 to 30. Earlier the Soviets had said that Salyut 6 was to be re-used and that manned flights would resume in 1980. The December window was used to test fly an unmanned version of the new Soyuz ferry.

The test vehicle, dubbed Soyuz-T, was a much improved version of the two-man Soyuz 12 type ferry used for flights to the Salyut 3 to 6 stations. Failures of Soyuz 15, 23, 25 and 33 to dock with Salyuts 3, 5 and 6 and their subsequent emergency return to Earth validated the Soviet planners' desire to have a vehicle with far more reliability and versatility. While most western observers were anticipating imminent test flights of the much publicised "Kosmolyot" space plane (probably to be used for military flights) the Soviets were quietly perfecting an improved Soyuz utilising the latest advances in Soviet electronics and hardware. It must be recalled that most of the systems of the Soyuz in use were first flown as long ago as

* *References and acknowledgements as Part 1*

1966. The improved Soyuz was test flown under the label of Cosmos 1,001 and 1,074. The latter vehicle was in space for 60 days qualifying it for extended flight.

Soyuz-T exhibited several significant design modifications including:

- Introduction of an Autonomous Onboard Computing Complex (ABKK) capable of flying the mission profile without human assistance.
- Improved telemetry rates. The ABKK provides onboard and FCC digital cathode displays of specific systems in a *processed* form, an impovement on the previous analogue sequencers.
- Re-introduction of solar panels for the generation of electricity enabling Soyuz-T to remain in space longer than the two days allowed to the Soyuz 12 type ferry in the event of docking difficulties. Extra power for the station also can be gained from the panels.
- Introduction, for the turbine driven Soyuz motor (SKDU), of a Salyut 6 type combined engine installation (ODU). On Soyuz-T the main engine and 4 attitude control thrusters use the same fuel supply. The attitude control engines also act as reserve to the main engine. The ODU exhibits higher thrust and manoeuvring capacity than the SKDU. Unification of the engines makes more propellant available for further docking attempts should the initial one fail. Lack of manoeuvring propellant was a factor in the abandonment of the Soyuz 15 and 23 flights.

Also Soyuz-T is provided with a colour TV camera (previously only a B/W one was carried); improved radio communication, orientation and descent systems. In addition significant modifications have been made to the internal layout suggesting that Soyuz-T has accommodation for 3 men. Vladimir Shatalov once called Soyuz "the spaceship of the future"; clearly the Soviets intend to use them for the foreseeable future in their civilian space programme.

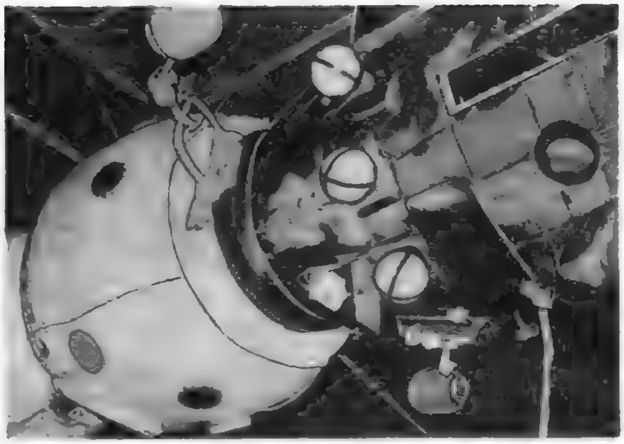
Soyuz-T in Flight

Soyuz-T was launched from Baikonur at 1230 (all times GMT) on 16 December 1979 into an initial orbit of 201×232 km×51.6° inclination; period 88.6 minutes. A Washington source noted that launch had occurred 73 minutes after Salyut's pass over the cosmodrome. This was later than normal Soyuz (no later than 30 minutes) and Progress (45 to 60 minutes) launches, indicating that some time was to elapse before the announced intention to dock with Salyut 6. That period was three days during which time the craft was manoeuvred and checked out. Soyuz-T performed impeccably, Soviet engineers announced.

At 1405 on 19 December Soyuz-T made an apparently flawless docking with the front docking unit of Salyut 6. The docking, performed entirely with Soyuz's ABKK, exhibited differences to earlier dockings in that Soyuz-T flew an approach path that was both above and in front of Salyut, losing altitude to meet the station, as opposed to catching up with the station from behind, the normal practice.

The Salyut 6/Soyuz-T complex was in an orbit at a height of 342×362 km; period 91.3 minutes after the docking. On 25 December the Soyuz-T ODU was used to raise the orbit to one with a 91.9 minute period; height was 370×382 km. The complex was then allowed to sink by atmospheric drag with Soyuz-T powered down.

By 29 February 1980 the orbit was 343×369 km; period 91.5 minutes. On 23 March, at 2104, Soyuz-T was undocked from Salyut 6 leaving the station in a 344×363 km orbit; period 91.4 minutes. Following two days of autonomous tests Soyuz-T made a nighttime landing in Kazakhstan at 2150 on 25 March. Soyuz-T had been in flight 100 days 9 hours and 20 minutes.



Front section of Salyut 6 with a Soyuz spacecraft in the docked position.

Theo Pirard

Cosmonauts who had "flown" the Soyuz-T prototypes on the ground praised the new spacecraft's performance. Serial production of the Soyuz-T type spacecraft has begun.

Progress 8 in Orbit

No sooner had the excitement over the return of Soyuz-T abated than the first act of the fourth long term expedition to Salyut 6 was played out with the launch of Progress 8 at 1853 on 27 March. Progress was commanded over the next two days to a docking with the rear docking unit of Salyut 6 at 2001 on 29 March. The next day Progress 8's SKDU was used to trim the Salyut's orbit in readiness for the launch of the new all Soviet crew. Following the trim Salyut 6/Progress 8 was in a 348×360 km orbit; period 91.4 minutes, perfect for a manned launch.

Soyuz 35

Preparations for the launch of the fourth main crew of the Salyut 6 space station had not gone as planned. Cosmonauts Leonid Popov and Valentin Lebedev, who had been the reserve crew of the Soyuz 32 flight (Popov was also reserve to Valery Bykovsky on Soyuz 22, Lebedev may have been reserve Flight Engineer for that flight), had almost completed their training when, in early March, Lebedev seriously injured his knee during trampoline exercises. The injury required an immediate operation. The Soviets chose not to fly their reserve crew but to put an experienced FE with the rookie Popov. All of the experienced FEs offered their services and Valery Ryumin was chosen.

During the medical preparations for the flight Popov had spent many nights sleeping with his feet above the level of his head. He spent many hours on a special revolving table with a chair on it. The table, capable of moving in two axes with the chair spinning at the same time, is a relatively new device with which the Soviets are trying to avoid vestibular problems.

So it was than on 9 April, just over 7 months after returning from Salyut 6, Valery Ryumin found himself atop an A2 booster in the Soyuz 35 cabin awaiting the launch. Both he and Popov looked relaxed. The launch occurred at 1338. Some 9 minutes after the start Popov (call sign Dneiper) and Ryumin were gazing down on the Earth from orbit.

Following a normal manned rendezvous lasting 24 hours the *Igla* navigation system of Soyuz 35 was activated when the spacecraft was only 10 km from Salyut 6. FCC was able to watch the docking *via* Soyuz's TV camera after it was switched

on some 600m away from the station. Docking occurred at 1516 (10 April) at a point over the Caspian Sea.

On Board Salyut 6

After equalising air pressure between Soyuz and Salyut, at 1826:11, the Dneipers (as the crew was known) opened the hatch between the vehicles and entered the station. In an amusing sidelight Ryumin opened a letter he had left for the next crew after vacating the station on 19 August 1979, never dreaming that he would be the recipient of his own note. Ryumin confided that he was not in the habit of writing letters to himself! In another humorous aside Ryumin showed the FCC specialists, watching via TV, a cucumber which he said had grown in the station's hydroponic installation without any human assistance, such as watering; after stunning the biologists he admitted the cucumber was plastic.

These incidents showed that the crew were reacting quite normally to the spaceflight. Popov's pulse (normal average 62 beats/min) had reached 125–133 before launch and 114 during launch. Ryumin, surprisingly for the space veteran he is, had a maximum pulse rate of 178 during launch.

Popov was initially a little hasty in his movements around the station but, with Ryumin's advice, soon learned to pace himself. The Dneipers suffered the usual congestion in their cranial arteries and slight vestibular disorders. But in spite of these "normal" spaceflight complaints they were in good health. Their programme of medical and physical exercises was initiated as soon as they had settled in.

The Dneipers' first work task was to activate the station's systems and "demothball" the life-support systems. Within the first day of boarding Salyut 6 these urgent tasks had been completed. Pressure was stabilised at 730 mm on the mercury column; temperature was 20° C.

The hatch to Progress 8 was opened on 11 April and the Dneipers began the unloading operation. The cargo craft carried the usual supplies of propellant, food, clothes, LSS regenerators, water, hygiene facilities, etc., as well as some new equipment.

The cosmonauts were scheduled to carry out a great deal of repair and maintenance work before the formal experiment programme could begin in earnest. Much of the equipment aboard Salyut had been working for 2½ years, about double the planned lifetime of the station. A new 80 kg buffer battery was connected as was a replacement battery in the steering unit. The batteries were replaced within one orbital nighttime period as opposed to the two periods budgeted for pre-flight. The radio communications system was checked; new command and warning systems were installed and checked; conditioning units in the water regeneration system were replaced; scientific equipment, such as the Elena-F gamma ray detector, was checked; air was pumped into the station's compartments from Progress 8 and, finally, the clocks were synchronised with those at the FCC. The repair and maintenance work, completed ahead of schedule, took about two weeks. In addition the cosmonauts watched the Earth, conducted medical and biological tests, obtained semiconductors from the Splav-01 and Kristall furnaces and worked to the now established routine with weekends off.

Progress cargo craft docked with Salyut 6 on the aft airlock.
Theo Pirard

At 1751:30 on 24 April the Progress 8 SKDU was fired for exactly 81 seconds to raise the station's orbit from a near circular 349×353 km to one with a height of 340×368 km, period 91.4 minutes. The station's oxidiser tanks were then topped up. At 0804 on 25 April Progress 8 undocked and the next day, at 0654 its SKDU was fired for the last time to send the cargo craft, loaded with used equipment, spiralling to destruction in the atmosphere above the Pacific Ocean.

Progress 9

Just one day after the demise of Progress 8, on 27 April, the ninth Progress cargo spacecraft was launched from Baikonur at 0624. The ship successfully docked with Salyut 6/Soyuz 35 at 0809 on 29 April. "It's becoming like a rail schedule," a Soviet journalist commented.

Along with the usual supplies of mail, food, clothes, etc., Progress 9 carried a new motor for the Biogravistat centrifuge which the crew installed. There were also replacement gas analyser filters, new VCR parts, the Lotos device for moulding parts from polyurethene, including small Misha Olympic symbols to be presented to "favoured" guests to the Soviet capital during the Summer Olympic games (these were to be brought to Earth aboard the Soyuz 35 ship when the Soviet/Hungarian crew, who flew in late May returned).

The main unloading operations were left until after the cosmonauts and FCC staff had celebrated the May Day holiday. During the two-day rest the Dneipers watched the May 1st Red Square parade and spoke to their relatives via the Earth-Orbit TV link and also conducted sporadic Earth observations tasks.

In a major innovation to the system of water supply Progress 9 delivered the Rodnik system by means of which 180 kg of water was pumped directly into a tank aboard Salyut. Before this system was adopted water was carried to the station in individual 5 kg bottles each of which had to be manhandled by the crewmen into the supply section of the station.

The unloading of Progress 9 went smoothly and the cosmonauts work with it was soon completed and on 16 May the cargo ship's SKDU was used to trim the orbit of the complex to 349×369 km, period 91.5 minutes. At 1851 on 20 May Progress 9 was commanded to undock from the complex and two days later the ship's SKDU was fired to send it to destruction in the atmosphere.

Soyuz 36 Preparations

Even as the Progress 9 was being manoeuvred out of orbit the carrier rocket for the next flight was being rolled out at Baikonur. The A2 rocket was scheduled to carry into orbit, for a rendezvous with Salyut 6, the long-delayed Soviet/Hungarian crew who had had their flight cancelled just before their scheduled take-off on 5 June 1979.

For the Soyuz 36 flight, as usual for all Interkosmos flights, two crews were trained. The first comprised Valeri Kubasov (USSR) and Bertalan Farkas (pronounced Farkash), a 30-year old captain in the Hungarian Air Force, and Vladimir Dzhanibekov (USSR) and his companion Bela Magyari, also 30 and also a captain in the HAF.

The selection board eventually approved Valery Kubasov and Bertalan Farkas as the prime crew of the flight with Dzhanibekov and Magyari serving as their reserves. The flight was scheduled for launch on 26 May – the first launching opportunity of what was to become a busy landing window.

To be continued

17th EUROPEAN SPACE SYMPOSIUM

The three-day meeting held at the Royal Commonwealth Society, London, from 4-6 June 1980 proved most successful, with the presentation of many high-quality papers on the theme of "Astronautics in the 1980s and Beyond."

Sponsored by the BIS, AAAS, AIDAA and DGLR and co-sponsored by Eurospace, the symposium had an attendance of about 70 participants.

We were particularly pleased to welcome Mr. Erik Quistgaard, the new Director General of the European Space Agency* who gave the opening address.

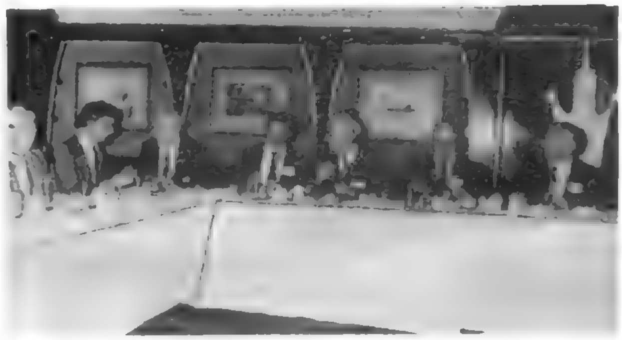
"We in Europe", he said, "need to build a bridge between the present and likely futures, and therefore your Symposium is welcomed, as it brings together prospective ideas for the distant future as well as presentations on the present achievements and extensions. The difficulty with this bridge we have to build is that the location of the other side is not known with certainty; there is not a single Future in space, but many scenarios with varying probabilities ...

"Apart from the scientific research in space which will always remain one of the most advanced intellectual challenges, what is in front of us in the field of applications is generally called "Space Industrialisation" and can be broadly split into 4 areas corresponding also to 4 steps:

- *Space Based Information Services*, covering not only communications but also meteorology, remote sensing, navigation ... This step has already started and future orientations in this area can be predicted with a good probability. An evolution towards large-dimension systems (single physical structures, or multi-spacecraft systems) will result from 2 factors:

the technical capabilities of the new transportation systems, allowing larger payloads and assembly and repair in orbit; and the economic considerations at system level, i.e. what has been called the "complexity inversion" factor (when a system has, for example, many thousand users, simplicity on the ground is imperative, hence complexity in space). However, how large will a "large system" be (3 tons or 30 tons)? This remains to be studied, at least in the European context, even if the US tendency seems to be towards very large dimensions as, for instance, the "Public Service Platform" already studied in detail (30 tons, 500 kw electric power, 23 antennae for integrated services such as: video broadcast education, national information services, personal voice communications, teleconferencing, electronic mail ...).

- *Products made in space*: studies have already identified which special materials of high cost-to-mass ratio could benefit from being manufactured in space. The commercial exploitation of this new sector of activity is likely, although it has to be preceded by an experimental research phase, and its actual implementation will largely depend on the evolution of the cost of transportation and orbital operations.
- *Application of space to the energy problem*: there are in this sector no limits to the human imagination, starting from proposals on the indirect effects – energy savings – via the improvement of Information Services, and going up to proposing the modification of the total solar flux on Earth through gigantic optical systems (700 km diameter!), in comparison with which the Solar Power Satellite itself seems to be quite straightforward to develop ...
- And finally, *population or colonisation of space*, including permanent space settlements, exploitation of space materials from the Moon, Mars or the asteroids ...



EUROPEAN SYMPOSIUM BANQUET. *Top*, BIS President G. V. E. Thompson and BIS Past-President Professor G. V. Groves (left) welcome guests at the Strand Palace Hotel. *Below*, L. J. Carter, Executive Secretary and members of the Council with Symposium participants during dinner. The Society has received many compliments on the arrangements made for this highly successful international meeting.

Keeping the above perspective in mind, even if part of it might look like science-fiction, the main question for Europe is: what to do in the next decade?

As we have already seen and we will see during this Symposium there is, in the fields of scientific research and exploration, and of space applications, a tremendous amount of ideas and also of already defined mission proposals. What is missing is the political drive required to provide the means necessary for meeting these intellectual challenges.

The first step is therefore to define a long term strategy for European space efforts, with the cooperation of all interested parties, including governments' representatives and space agencies as well as industry and users. The European Space Agency is, from its mandate, the normal focal point for this elaboration which has already been initiated and needs to be pursued vigorously.

The preparation of the above strategy raises a huge number of questions, whose answers, even when they seem obvious to some, must be confirmed by thorough studies, for instance:

- at the political level, will Europe try to be autonomous in space, or will it accept some degree of dependence? Is European solidarity a prerequisite to future success?
- at the socio-economic level, will space activities continuously expand or will there be a saturation phase due to socio-economic factors? What is the European capacity in

* *The former Director General Mr. Roy Gibson – the current President of the International Astronautical Federation and a Fellow of the B.I.S. – retired from ESA on 15 May.*

terms of space investments? What will be the correct balance between research/exploration and the applications contributing to Man's well-being?

- at technical level, is the presence of the Man in Space operations necessary or only desirable? In particular is Man required for the transportation system? Will the technological development push more toward highly concentrated space systems or distributed networks? Have the expendable launchers still some prospects? . . .

Derived, at least in part, from the considered answers to the above questions, the European strategy for the next ten years must fill the gap between the current space programmes or the programmes under preparation and the more distant future defined in terms of plausible scenarios. While consolidating our present position and satisfying – through the use of the space transport elements we are developing – the short and medium term needs resulting from economic and market forces, we also must pay sufficient attention to the potential objectives of the future.

As I have already stated, one key element of the success of Europe's future undertakings is the political drive in support of a common aim, sufficiently ambitious to require a strong solidarity between our countries, to raise up again this solidarity which is, for me, a prerequisite to the maintenance and improvement of Europe's present position, I believe we in Europe need to define and undertake a major driving project, including such transportation elements and orbital systems as will give Europe, in the early 1990s, the ability to play a significant role in the future industrialisation of space as well as in the scientific space research field."

Several speakers urged consideration of a small European Space Shuttle.

Arrangements are being made to publish a selection of papers from the 17th European Space Symposium in the BIS *Journal*.

£75,000 STAGE-2 APPEAL

As members will already know we urgently need to increase our income to meet the ravages of inflation. Being an independent body unsupported by Government funds, the Society has to rely on the generosity of its members.

We are therefore most grateful to all members and friends of the Society who have rallied to our £75,000 Stage-2 Appeal. The first objective is to repay the £30,000 Bank Loan which covered the construction costs of the final stage of our new Headquarters Building. With the very high interest charges that are currently being incurred by the Society the urgency of the Appeal can hardly be over stressed.

If you have not already done so we ask every member to recognize the work and needs of the BIS by sending a donation. As our President has stated, your donation will really count whatever the amount – large or small.

We never cease to be surprised by the generosity of our members (writes the Executive Secretary):

- **Pat Ladd**, of Trowbridge, has come forward to help the Society once more. Besides the very nice Lectern and Notice Boards which he gave previously, he has now donated a fine Display Cabinet for installation in the Society's new Library and which will be used to show off collections of books, manuscripts, letters, stamps and small artifacts.

  To Pat we extend our most grateful thanks. We feel sure that other members will feel the same way about it every time they see something of interest exhibited in the new cabinet.

- **Ken Kirkland** has also had an eye on members' creature comforts. His gift takes the form of three fans, installed in the upper windows of the Golovine Conference Room. Not content with that, he added two more fans down in the basement to rid it of a musty odour, as well as adding an isolating valve to our boiler for good measure. All sound basic stuff . . .

  All we need now is for someone to renovate the back of the building. Our HQ looks good from the front (the *Autocar* recently featured an advert for a sleek, glossy-looking new car with the front of our offices in the background) but please don't look at the rear!

Honour for BIS Fellow

We are pleased to report that Miss Penny Wright (Fellow) was awarded the MBE in the Queen's Birthday Honours (1980) List. The award was given for research on airborne electronic equipment.

Miss Wright was a member of the team which produced the BIS Daedalus Report for an unmanned starship. She has a keen interest in all aspects of Astronomy and Electronics related to astronautics.

THE COSMONAUTS – Part 18

By Gordon R. Hooper

Continued from February 1980 issue, page 65

Colonel Vladimir Vasilyevich Kovalyonok (or Kovalenok)

Vladimir Kovalyonok was born on 3 March 1942, in the village of Byeloye, Krupsky District, near Minsk in Byellorussia. His father was a farmer. After studying at the Balashov Higher Air Force School, and graduating in 1963, he served in the Soviet Air Force flying military transport planes. He logged over 1600 hours in the air, and also qualified as a paratroop instructor. He joined the CPSU in 1962 at the unusually young age of 20.

In 1967, he was selected as a cosmonaut, and subsequently took part in the ground control of manned flights and orbital stations. In 1976, he graduated from the Yuri Gagarin Air Force Academy while working at the Cosmonauts Training Centre.

His first assignment was as back-up to Pyotr Klimuk, the commander of Soyuz 18 in May 1975. His first spaceflight came as commander of Soyuz 25, launched on 9 October 1977. When the crew attempted to dock their spacecraft with Salyut 6, they were prevented from doing so by a fault in the docking system. They were forced to make an emergency re-entry and touchdown after a mission lasting 2 days and 46 minutes. Kovalyonok was later awarded the Order of Lenin.

In late 1977, he served as back-up to Yuri Romanenko, the commander of Soyuz 26, and then as back-up to Vladimir Dzhanibekov, the commander of Soyuz 27. His second spaceflight came as commander of Soyuz 29, launched on 15 June 1978 in a second attempt to link up with Salyut 6. This time, the docking was successful, and Kovalyonok and Alexander Ivanchenkov spent 139 days 14 hours and 48 minutes in space, setting a new record. During the mission, Kovalyonok took part in an EVA lasting 2 hours and 5 minutes.

Following his return, Kovalyonok was awarded the title of Hero of the Soviet Union, and was presented with the Order

Flight engineer Valery V. Ryumin and Lt Col Vladimir A. Lyakhov. *Below*, Col. Vladimir V. Kovalyonok.

Novosti Press Agency

of Lenin and the Gold Star Medal. In addition, he was awarded the Gruenwald Cross, First Class by Poland, and the Order of Karl Marx together with the title of Hero of the GDR from the German Democratic Republic.

Vladimir Kovalyonok is married, and he and his wife Nina have a 14 year old daughter, Inessa. Kovalyonok has been described by other cosmonauts as stubbornly persistent in his work. He was the 40th Soviet cosmonaut.

Valery Viktorovich Ryumin

Valery Ryumin was born on 16 August 1939, in Komsomolsk-on-Amur, in Siberia. After graduating from a technical college in Kaliningrad, he served in the Soviet Army. In 1961, he entered the Moscow Timber Industry Institute's Department of Electronics, and upon graduating, he went to work in Sergei Korolyov's design bureau. He distinguished himself as an engineer with great knowledge and initiative, and took part in the development and testing of new space equipment. He is an expert on electronic control systems.

Ryumin joined the CPSU in 1972, and was selected as a cosmonaut in 1973. He took part in the ground control of manned and unmanned spaceflights, and served as a CapCom onboard the *Akademik Sergei Korolyov* during the ASTP flight in July 1975. He also became a leading designer in the Salyut programme, and was involved in the design of the Salyut 6 space-station.

His first flight came as flight-engineer onboard Soyuz 25, launched on 9 October 1977. After 1 day in orbit, the crew attempted a docking with Salyut 6, but this failed. The crew were forced to make an emergency re-entry and touchdown, after a flight lasting only 2 days and 46 minutes. Ryumin was subsequently awarded the Order of Lenin, but did not receive the customary award of the title Hero of the Soviet Union.

His next assignment was as back-up to Alexander Ivanchenkov, the flight-engineer onboard Soyuz 29, launched on 15 June 1978. He made a second flight as flight-engineer in Soyuz 32, launched on 25 February 1979. On this occasion, the docking with Salyut 6 was successful, and Ryumin at last boarded the space-station. For nearly 6 months, he and Vladimir Lyakhov worked onboard the station conducting a wide ranging programme of experiments and studies.

During their flight, the two men carried out an EVA to free a radio-telescope which had failed to detach from the space-station. Ryumin spent 1 hr and 23 min in open space, and was the 8th Soviet cosmonaut to conduct an EVA. The two men returned to Earth on 19 August 1979 after a flight lasting 175 days and 36 minutes – a new record.

Upon his return, Valery Ryumin was made a Hero of the Soviet Union and was awarded the Order of Lenin and Gold Star medal. He is married, and his wife is an engineer. They have two children, a daughter, and a son, Vadim. Ryumin is a passionate hockey fan, and is said to be serious and efficient. Lyakhov has described him as "a very quiet, reasonable and business-like man . . . an excellent engineer."

In early 1980, Ryumin was involved in the training of Leonid Popov and Valentin Lebedev for the forthcoming Soyuz 35 flight. Unfortunately, Lebedev injured his knee in training some 6 weeks before launch. Ryumin apparently volunteered to take his place, although he was not Lebedev's back-up. He therefore made a third spaceflight as flight-engineer onboard Soyuz 35, launched on 9 April 1980.

Popov and Ryumin docked their spacecraft with the Salyut 6 space-station and began reactivating it for another long-stay mission. At the time of writing, the two cosmonauts were still in orbit, with an announced goal of a six-months-plus stay.

Valery Ryumin was the 41st Soviet cosmonaut.

Lt-Colonel Vladimir Afanasevich Lyakhov

Vladimir Lyakhov was born on 20 July 1941, in Antratsit, in the Voroshilovgrad region of the Ukraine, in a large coalmining area. His father was a miner, but was killed during World War Two, when Lyakhov was only 3. From the age of 7, he was brought up by his step-father, Mikhail Grigoryevich Yurov. Vladimir enrolled in the Kharkov Higher Air Force School, and upon graduation in 1964, joined the Soviet Air Force. He joined the CPSU in 1963. He served in a fighter squadron in the Soviet Far East, and became an experienced pilot, flying in 14 different types of aircraft, including MiG 21's, and logging 1300 hours of flying time.

Lyakhov was selected as a cosmonaut in 1967, and shortly after qualified as a test-pilot. He holds the titles "Military Service Pilot, 1st Class" and "Test pilot, 3rd Class." In 1975, he graduated from the Yuri Gagarin Air Force Academy while working at the Yuri Gagarin Cosmonaut Training Centre. Also in 1975, he was assigned to a group of cosmonauts selected to prepare for flights to Salyut space stations.

His first assignment was as back-up to Vladimir Kovalyonok, the commander of Soyuz 29, launched on 15 June 1978. His first flight came as commander of Soyuz 32, launched on 25 February 1979. During a record-breaking flight lasting nearly six months, Lyakhov and Valery Ryumin carried out a series of experiments and tests onboard the Salyut 6 space station. When a radio-telescope attached to the station became entangled with other equipment, the two cosmonauts had to perform an EVA lasting 1 hr and 23 min, during which Lyakhov became the 9th Soviet cosmonaut to carry out a spacewalk. The two men returned to Earth after a flight lasting 175 days and 36 min.

Following his return to earth, Lyakhov was made a Hero of the Soviet Union, and was awarded the Order of Lenin, Gold Star medal, and title of Pilot-Cosmonaut of the Soviet Union. He is married, and his wife is an accountant/economist. They have a son, Yuri, and also a daughter. Lyakhov also is a hockey fan, and is said to be "self-restrained" in character.

Vladimir Lyakhov was the 45th Soviet cosmonaut.

SATELLITE DIGEST – 141

A monthly listing of all known artificial satellites and spacecraft. A detailed description of the information presented can be found in the January 1979 issue, p. 41.

Compiled by Robert D. Christy

Continued from September–October issue

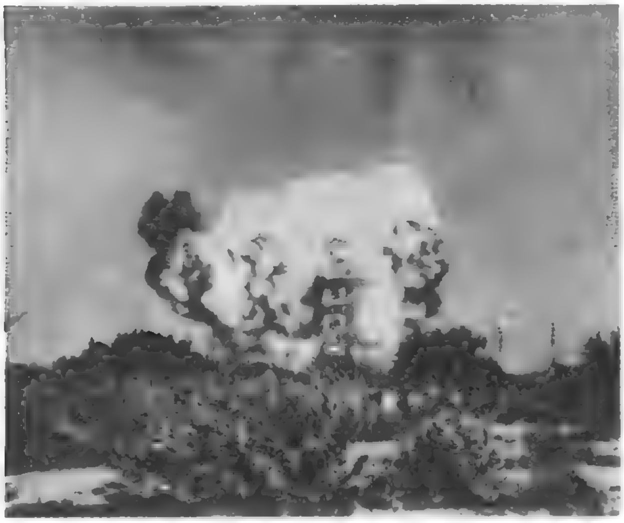
Name, designation and object number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch site, launch vehicle and payload/launch origin
Navstar 1980-32A 11783	1980 Apr 26.91 indefinite	Cylinder+4 vanes 450?		170	20288	63.02	354.97	WTR Atlas F DoD/USAF (1)
Progress 9 1980-33A 11784	1980 Apr 27.27 25 days 1980 May 22	Sphere+cone- cylinder 7000?	8 long 2.2 dia	185 244 333	255 350 362	51.65 51.65 51.63	88.84 90.39 91.43	Tyuratam A-2 USSR/USSR (2)
Cosmos 1176 1980-34A 11788	1980 Apr 29.49 600 years?	Cylinder?	6 long? 2 dia?	250	265	65.00	89.66	Tyuratam F-1-m USSR/USSR (3)
Cosmos 1177 1980-35A 11789	1980 Apr 29.56 44 days (R) 1980 Jun 12	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	165	341	67.16	89.59	Plesetsk A-2 USSR/USSR (4)
Cosmos 1178 1980-36A 11793	1980 May 7.54 15 days (R) 1980 May 22	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	196 354	390 413	72.84 72.83	90.43 92.27	Plesetsk A-2 USSR/USSR (5)
Cosmos 1179 1980-37A 11796	1980 May 14.54 500 years	Cylinder? 700?	2 long? 2 dia?	301	1550	82.97	103.60	Plesetsk C-1 USSR/USSR (6)
Cosmos 1180 1980-38A 11798	1980 May 15.23 12 days (R) 1980 May 26.9	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.2 dia?	238	290	62.81	89.79	Plesetsk A-2 USSR/USSR
Cosmos 1181 1980-39A 11803	1980 May 20.39 1000 years	Cylinder? 700?	2 long? 2 dia?	975	1007	82.95	104.99	Plesetsk C-1 USSR/USSR (7)
Cosmos 1182 1980-40A 11808	1980 May 23.30 13 days (R) 1980 Jun 5.2	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	205 210	215 250	82.32 82.36	88.74 89.14	Plesetsk A-2 USSR/USSR (8)
Soyuz 36 1980-41A 11811	1980 May 26.764	Sphere+cone- cylinder 6600?	7.5 long 2.2 dia	191 250 333	265 314 354	51.60 51.62 51.62	88.99 90.09 91.35	Tyuratam A-2 USSR/USSR (9)
Cosmos 1183 1980-42A 11816	1980 May 28.50 14 days (R) 1980 Jun 11.3	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	199 377 356	387 418 415	72.80 72.90 72.90	90.42 92.54 92.31	Plesetsk A-2 USSR/USSR (10)
NOAA 7 1980-43A 11819	1980 May 29.454 1 year	Irregular box+ panel 1405	3.71 long 1.88 dia	265	1447	92.23	102.12	WTR Atlas F NOAA/NASA (11)
Cosmos 1184 1980-44A 11821	1980 Jun 4.32 60 years	Cylinder+2 panels? 2500?	5 long? 1.5 dia?	620	647	81.23	97.44	Plesetsk A-1 USSR/USSR (12)
Soyuz T-2 1980-45A 11825	1980 Jun 5.596 3.93 days (R) 1980 Jun 9.52	Sphere+cone- cylinder+2 panels 7000?	7.5 long? 2.2 dia	195 266 333	231 315 348	51.63 51.60 51.63	88.69 90.27 91.29	Tyuratam A-2 USSR/USSR (13)

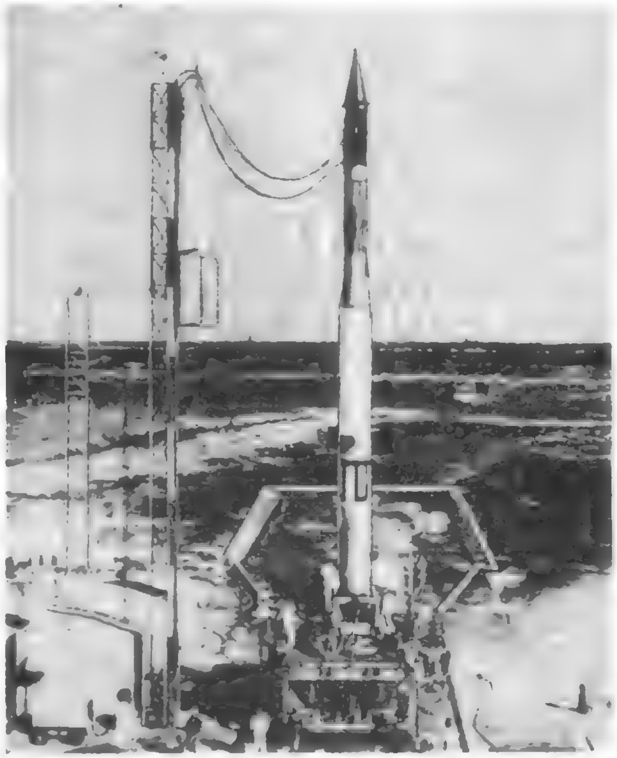
Name, designation and object number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch site launch vehicle and payload/launch origin
Cosmos 1185 1980-46A 11827	1980 Jun 6.29 14 days (R) 1980 Jun 20	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	212 259	282 283	82.33 82.44	89.48 89.98	Plesetsk A-2 USSR/USSR (14)
Cosmos 1186 1980-47A 11829	1980 Jun 6.46 1½ years	Octagonal ellipsoid? 550?	1.8 long? 1.5 dia?	471	518	74.03	94.56	Plesetsk C-1 USSR/USSR
Cosmos 1187 1980-48A 11837	1980 Jun 12.52 14 days (R) 1980 Jun 26	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	198 225	305 289	72.86 72.85	89.51 89.69	Plesetsk A-2 USSR/USSR (15)
Horizont 4 1980-49A 11841	1980 Jun 13.03 indefinite	Cylinder+2 panels? 5000?	5 long? 2 dia?	36382	36637	0.96	1473.2	Tyuratam D-1-E USSR/USSR (16)
Cosmos 1188 1980-50A 11844	1980 Jun 14.87 12 years?	Cylinder-cone+6 panels? 1250?	4.2 long? 1.6 dia?	609 647	40128 39692	62.92 62.93	725.53 717.46	Plesetsk A-2-e USSR/USSR (17)
Meteor (30) 1980-51A 11848	1980 Jun 18.26 60 years	Cylinder+2 panels? 2200?	5 long? 1.5 dia?	583	665	97.94	97.24	Tyuratam A-1 USSR/USSR (18)
Big Bird 1980-52A 11850	1980 Jun 18.77 6 months?	Cylinder 13300?	15 long 3 dia	168	265	96.45	88.89	WTR Titan 3D DoD/USAF (19)
1980-52C 11852	1980 Jun 18.77 5000 years			1330	1331	96.63	112.33	WTR Titan 3D DoD/USAF (19)
Molniya-1(47) 1980-53A 11856	1980 Jun 21.77 12 years?	Cylinder-cone+6 panels 1000?	3.4 long 1.6 dia	630 633	40702 39686	62.83 62.83	737.68 717.05	Plesetsk A-2-e USSR/USSR (20)
Cosmos 1189 1980-54A 11863	1980 Jun 26.51 14 days (R) 1980 Jul 10	Cylinder+sphere +cylinder-cone? 6000?	6 long? 2.4 dia?	197 225 225	302 290 331	72.87 72.86 72.86	89.53 89.70 90.11	Plesetsk A-2 USSR/USSR (21)
Progress 10 1980-55A 11867	1980 Jun 29.19	Sphere+cone- cylinder 7000?	8 long 2.2 dia	183 206 325	264 255 340	51.62 51.62 51.63	88.91 89.05 91.11	Tyuratam A-2 USSR/USSR (22)
Cosmos 1190 1980-56A 11869	1980 Jul 1.36 120 years	Cylinder+paddles? 750?	2 long? 1 dia?	792	804	74.05	100.87	Plesetsk C-1 USSR/USSR
Cosmos 1191 1980-57A 11871	1980 Jul 2.04 12 years?	Cylinder-cone+6 panels?	4.2 long? 1.6 dia?	599 610	40130 39755	62.65 62.66	725.36 718.39	Plesetsk A-2-e USSR/USSR (23)
Cosmos 1192- 1199 1980-58A-H 11875-11882	1980 Jul 9.03 10 000 years	Ellipsoids? 40?	0.8 long? 0.6 dia?	1397 1415 1433 1451 1469 1472 1474 1473	1474 1475 1475 1475 1476 1493 1510 1532	74.02 74.02 74.02 74.02 74.02 74.02 74.02 74.02	114.62 114.82 115.02 115.22 115.42 115.65 115.85 116.09	Plesetsk C-1 USSR/USSR (24)

Continued on page 363

A SURVEY OF LAUNCH VEHICLE FAILURES

By Robert G. Bramscher





VANGUARD. Final preparations are made for the launching of America's first satellite at Cape Canaveral. *Left*, the rocket fails to develop sufficient thrust, topples over and explodes in a sea of flames. The date was 6 December 1957.

US Navy

Introduction

The imminent arrival of the operational Space Transportation System, utilizing the reusuable Space Shuttle, brings near the end of the era of the expendable space launch vehicle in the United States. Since the launch of Sputnik I on 4 October 1957, the spacefaring nations, especially the United States and the Soviet Union, have spent untold billions of dollars and roubles developing and producing the multitude of expendable launch vehicle models which have taken instruments and man into space. In the United States in particular, the number of models of expendable launch vehicles has added to the expense of space exploration and has probably reduced the overall reliability of the boosters. In 1973 alone, 25 missions were flown using 10 booster variations.

In retrospect, the expendable launch vehicle appears to be a unique product of the cold war. The early literature of space flight did not hypothesize the immense expenditure of funds which went into the launch operations of the first twenty years of the space age. Only such spending could make available the 839 launch vehicles which, up to the end of 1978, were used by the United States. By the end of 1977, a staggering 1807 known launches were made to orbit or beyond by all nations. The bulk of these launch vehicles ended in a watery tomb. A few were destined to become some of the most spectacular fireworks displays the world has ever witnessed. Not one of these rockets was capable of reuse.

The advent of the Space Shuttle in the United States, and its cousin now under development in the Soviet Union, will greatly reduce the dependency of those nations on expendable boosters and at the same time, should make human exploitation of near Earth space a much more economical and attractive possibility. As the era of the expendable launch vehicle draws to a close in the United States, it seems appropriate to review the record of American launch vehicle failures in the context of the overall American space programme. It also seems appropriate to compare the experience of the United States with that of nations other than the USSR.

Methods, Definitions and Clarifications

Prior to discussing specific vehicles and their performance, it is important to define exactly what the term "vehicle failure" means in terms of this article. For this purpose, launch vehicle failure includes all launches which were intended, but failed, to place all or part of the vehicle into an orbit around the Earth, or launch that vehicle into more distant space, in such a way that the object or objects launched would have been awarded an international designation if the launch had been successful. Thus, only launches which failed to qualify for an international designation, but would have so qualified if successful, are included as failures.

Having stated the rule, we must now discuss the inevitable exceptions. Fortunately, they are few enough in number so they can be briefly discussed here. The Atlas Able 4 vehicle lost during a static test on 24 September 1965 is included because it resulted in the complete destruction of an already scheduled launch attempt. A failure which occurred in such a way that the launch could be scheduled later with the same booster would not be included as a failure. An example is the explosion on 21 January 1959 of the Agena stage of a Thor-Agena A. The Thor was saved and thus the mission is not counted as a success or failure but is listed for informational purposes in Table 2.

Several vehicles placed objects in orbit but the payload or parts thereof did not reach orbit. These launches are included in the Tables detailing the failures of the various types of vehicles. This procedure is used to avoid the problem of a vehicle being considered a statistical failure and success at the same time. This problem is faced with three vehicles: the Atlas D Launch of 14 July 1966 which launched OV1-8 into orbit but failed to orbit OV1-7; the Atlas F (Satar) launch of 27 July 1967 which orbited OV1-12 and OV1-86 but failed to orbit OV1-11; and the Delta launch of 21 October 1971 in which the payload failed to orbit but the second stage received the international designation 1971-91A.

Building Blocks of Success

The early years of space flight were marked by large numbers of launch vehicle failures. These failures were, however, the foundation upon which later successes were built. In its lifetime, the Vanguard programme achieved 3 successful satellite launches in 11 attempts for a success record of 27%. The experience gained in the development of the Vanguard was used to create the second stage of the Thor Able booster which achieved 4 successes in 7 flights for a 57% success rate. That programme in turn was a stepping-stone to the remarkably successful Delta launch vehicle which has had 133 successful launches in 140 flights achieving 95% success.

Similar progress was made with the Thor Agena. That programme grew from the Thor Agena A vehicle which scored 9 successful launches in 15 attempts (60%) to the long Tank Thrust-Augmented Thor Agena D which launched 39 payloads into orbit in 41 attempts for a 95% success rate.

In the five years following the first satellite launch the United States made 167 launch attempts and succeeded 114 times for a success rate of 68%. In the five year period including the years 1968 through 1972, 187 launch attempts were made, with 177 succeeding, for an average of 95%. Prior to 1965 the United States had never achieved a yearly success average of 90% or above. After 1965 the United States never dropped below a 90% yearly success rate.

Commencing in the mid-1960's, several booster programmes were initiated by the United States which maintained a 100% success rate. These vehicles included the Saturn I and IB (13 launches), the Saturn V (13 launches), the Titan II-Gemini (11 launches), the Thor Burner 2 (21 launches) and the Titan IIID (16 launches). The Thor Burner 2 and Titan IIID programme continue to this day. Without the heartbreaking failures of the early years, these remarkable records would not have been possible. The fact that no American astronaut has been lost during a launch, or even had a mission aborted, is also a direct result of the many lessons learned earlier.

Launch Vehicle Genesis

The world became painfully aware of the uncertainties involved in rocket development on 6 December 1957. Although the news media had carried numerous stories and photos of military missiles exploding on or above the launch pad prior to that date, the illfated launch pad explosion of Vanguard TV-3 on that day had an enormous impact on the future US space programme. The fact that TV-3 was a development flight seemed to make little difference to the public and Congress. The "space race" that arose in the wake of the Vanguard failure made the extensive use of the expendable booster inevitable. There was just no time for the development of a reusable system during those years of crisis.

Between 6 December 1957 and 22 June 1959, the Vanguard vehicle suffered 8 failures and 3 successes (see Table 1). On 5 February 1958, TV-3bu suffered a control system malfunction after about 57 seconds causing the vehicle to breakup. The next six failures involved problems at the point of initial separation or after, indicating that the 1st stage defects had been corrected but that much work remained to be done to resolve the continuing upper stage anomalies.

The proficient design team under Wernher von Braun reaped the well deserved glory of launching America's first satellite (a feat which they were probably equipped to do a year or two earlier) but fared only somewhat better in their overall early success rate. The first, third and fourth launchings of the Juno I (Jupiter C) were successful. The second, fifth and sixth, however, all encountered upper stage problems indicating that the technology required for smooth operation of a multi-stage vehicle had yet to be perfected. The Juno II was the Army Ballistic Missile Agency follow-up launch vehicle to the Juno I. Between December 1958 and November 1960, this Jupiter-based satellite booster fired successfully in 5 out of 10 tries for a 50% average. On 16 July 1959, the attempted launch of Explorer S-1 failed when the Juno II guidance system failed after 5 seconds and the rocket proceeded to turn 180 degrees just above the launch pad and smash itself into the ground. The other four failures all involved the old problem of upper stage malfunction. The lessons learned in these launches paid dividends when the von Braun team moved on to the development of the Saturn family of boosters.

The Thor Able was the first US launch vehicle to achieve a percentage of success better than half. Out of seven launches, four were successful. This statistic is somewhat misleading, however, since one of these successes was the heartbreaking Pioneer 1 shot of 11 October 1958, when that probe reached 70,700 miles into space but returned to Earth after not quite achieving the velocity required to allow it to escape the Earth's gravity (see Table 1). The three Thor Able launch failures included the Pioneer launch of 17 August 1958 in which the first stage exploded after 77 seconds and the Pioneer 2 Moon probe of 8 November 1958 where the third stage failed to fire. The last Thor Able failure involved the attempted launch of Transit 1A in which the third stage also failed to fire.

The last of the very early launch vehicles was the Atlas Able. This booster was the only major category of satellite launcher that failed in every attempt. Atlas Able was utilized in a series of four attempts to fire probes at the Moon. Two Atlas Able 4 rockets were built and the first exploded in a static test on 24 September 1959, ending any chance of launching Pioneer P-1. The second Atlas Able 4 launched Pioneer P-3 on 26 November 1959 and was lost when the payload shroud fell off and the second stage failed to fire. Atlas Able 5A with Pioneer P-30 fell to a mid-ocean grave when the second stage failed to fire and Atlas Able 5B with Pioneer P-31 exploded after 70 seconds of flight. No further firings of the "hard luck" Atlas Able were attempted.

The Second Generation

The year 1960 saw the introduction of two launch vehicles that became workhorses of the first two decades of the space age. The first launchings of the Delta and the Scout were made that year. The Delta was a direct descendant of the Vanguard and the Thor Able. As such, it had the advantage of all the development work that had previously gone into those programmes. The launch of Delta 1 failed on 13 May 1960 when a 2nd stage attitude control failure occurred. Following that flight, however, Delta performed successfully for 22 missions until Delta 24 suffered a premature 3rd stage cut-off in March 1964. From that date to the end of 1978, the Delta programme suffered only five further complete launch failures in 123 attempts. A marginal booster failure occurred with the launch of Delta 86 on 21 October 1973 when the 2nd stage tumbled and ITOS E failed to orbit but the upper stage booster apparently did achieve orbit. Of the complete failures, three occurred because of problems in the main booster and the other four suffered upper stage malfunctions. This record certainly indicates that the early problems with multistage boosters had been solved. The success rate in eighteen years of Delta booster history stands at 95% (See Table 2).

As of the end of 1978, the Scout launch vehicle had performed successfully 85% of the time, launching satellites into orbit in 68 of 80 attempts (Table I). The Scout vehicle has been flown by both NASA and the USAF. As a USAF launch vehicle it was called the Blue Scout. The NASA launches are well documented, but the USAF launches, especially during the years 1962 and 1963 are still shrouded in some mystery.

The first three Scout failures were NASA attempts in 1960 and 1961. Scout 3 failed to launch Explorer S-56 on 4 December 1960 when the 2nd stage failed to ignite. Scout 5 failed on 30 June 1961 when the 3rd stage did not fire and Explorer S-55 never reached orbit. The guidance system failed on Scout 8 carrying Mercury-Scout 1 tracking equipment and the booster was destroyed after 30 seconds.

These NASA failures were followed by a series of seven

A Survey of Launch Vehicle Failures/contd.

Table 1 Early Launch Vehicles

Vehicle/Site	Payload	Date(GMT)	Reason for failure
Vanguard (E)			
TV-3	Vanguard	6 Dec 57	1st stage lost thrust, exploded after 2 seconds.
TV-3bu	Vanguard	5 Feb 58	1st stage control system malfunction after 57 seconds.
TV-5	Vanguard	28 Apr 58	bad 2nd stage shutdown preventing 3rd stage firing.
SLV-1	Vanguard	27 May 58	loss of attitude control at 2nd stage burnout.
SLV-2	Vanguard	26 June 58	early 2nd stage shutdown prevented 3rd stage firing.
SLV-3	Vanguard	26 Sep 58	below minimum 2nd stage performance prevented orbit.
SLV-5	Vanguard	14 Apr 59	loss of 2nd stage pitch control.
SLV-6	Vanguard	22 June 59	low tank pressures after 2nd stage ignition caused instability.
Juno I (Jupiter C)(E)			
RTV-5	Explorer 2	5 Mar 58	final stage failed to ignite.
RTV-8	Explorer 5	24 Aug 58	after separation, booster bumped into remaining stages.
RTV-9	Beacon 1	23 Oct 58	2nd stage failed to fire, premature separation.
Juno II(E)			
*RTV-10	Pioneer 3	6 Dec 58	insufficient thrust in 1st stage to achieve lunar distance.
RTV-12(Am16)	Explorer S-1	16 Jul 59	guidance failed, destroyed 5 sec.
RTV-13(Am19B)	Beacon 2	14 Aug 59	early booster fuel depletion and upper stage guidance failure.
–	Explorer S-46	23 Mar 60	no communication after 2nd stage burnout.
–	Explorer S-45	24 Feb 61	2nd stage malfunction caused 3rd stage failure to ignite.
–	Explorer S-45A	24 May 61	2nd stage failed to ignite.
Thor Able(E)			
Able 1(127)	Pioneer 0	17 Aug 58	1st stage exploded at 77 seconds.
*Able 1(130)	Pioneer 1	11 Oct 58	insufficient velocity to reach Moon.
Able 1(129)	Pioneer 2	8 Nov 58	3rd stage failed to ignite.
Able 2	Transit 1A	17 Sep 59	3rd stage failed to ignite.
Atlas Able(E)			
Able 4A	Pioneer P-1	24 Sep 59	exploded in static test.
Able 4B(20D)	Pioneer P-3	26 Nov 59	payload shroud fell off and 2nd stage failed to operate.
Able 5A(80D)	Pioneer P-30	25 Sep 60	2nd stage failed to ignite.
Able 5B(91D)	Pioneer P-31	15 Dec 60	exploded after 70 seconds.
Scout			
Scout 3 (WI)	Explorer S-56	4 Dec 60	2nd stage failed to ignite.
Scout 5 (WI)	Explorer S-55	30 Jun 61	3rd stage failed to ignite.
Scout 8 (E)	MS-1	1 Nov 61	guidance failed, booster destroyed at 30 seconds.
Blue (W)	Solrad 4B	26 Apr 62	–
Blue (W)	USAF metsat	24 May 62	–
Blue (W)	Transit 5A2	6 Apr 63	4th stage malfunctioned.
Blue (W)	USAF metsat	26 Apr 63	–
Blue (W)	USAF metsat	27 Sep 63	–
Blue (W)	ESRS	26 Jun 64	2nd stage exploded.
Blue (W)	OV3-5	31 Jan 67	4th stage failure.
Scout (W)	ESRO IIa	29 May 67	3rd stage failure.
Scout (W)	Explorer DAD-A; B	5 Dec 75	3rd stage nozzle failure.

* Launch was intended to escape Earth's gravity but failed to do so.
– Unknown or undisclosed.
(E) Eastern Test Range, (W) Western Test Range, (WI) Wallops Island

USAF failures. The exact reason for 4 of the 7 failures appears at this time to be undisclosed. Fourth stage malfunctions probably caused the loss of Transit 5A2 on 6 April 1963 and OV3-5 on 31 January 1967. The second stage exploded in an attempt to launch ESRS on 26 June 1964. Undisclosed malfunctions caused the loss of USAF meteorological payloads on 24 May 1962, 26 April 1963, 27 September 1963 and Solrad 4B on 26 April 1962.

On 29 May 1967 ESRO 11A was lost when the 3rd stage of a Scout failed. After that launch failure, there were 31 successful Scout launches before the failure of Explorer DAD A,B when there was a third stage nozzle failure on 5 December 1975.

Also introduced in 1960 was the Thor AbleStar. That launch vehicle flew successfully in 14 of 19 flights between 1960 and 1965 for a 74 percent success rate. The third Thor AbleStar failed to orbit Courier 1A when the first stage malfunctioned and the booster had to be destroyed after 2½ minutes on 18 August 1960. Transit 3A/Greb 2 suffered a second stage failure causing booster destruction by the Range Safety Officer on 30 November 1960. Composite 1 (carrying five payloads) and Anna 1A both suffered second stage failures and were lost on 24 January 1962 and 10 May 1962 respectively. The final failure resulted in the loss of Transit 5BN3 and 5N40 on 21 April 1964 and was caused by human error attributed to the flight control team.

The Thor Altair/FW4 booster was introduced in 1965 and suffered only one failure in its launch experiences. That failure occurred on 7 January 1966 during an attempt to launch a USAF meterological satellite by a Thor-FW4 booster and was caused by undisclosed malfunctions. This was the final launch of the Thor Altair/FW4 vehicle of 6 attempts.

The Thor Agena

The Thor Agena launch vehicle combinations will take a prominent place in the history of expendable boosters (Table 2). Between 1959 and the end of 1972, 186 launchings were made with the various Thor Agena configurations. Of those launch attempts, only 22 failed to orbit their payload for an overall success ratio of 88%. This figure is deceiving, however, since 12 of those failures occurred in the Discoverer programme utilizing the early Thor Agena A and Thor Agena B vehicles. Some authorities attribute a thirteenth failure to the Discoverer programme and indicate that they believe Discoverer 1, launched on 28 February 1959, never reached orbit although it received the international designation 1959 Beta. For the purpose of this article, Discoverer 1 is considered a failure.

Table 2 Thor Boosted Vehicles

Vehicle/Site	Payload	Date (GMT)	Reason for failure
Delta			
1 (E)	Echo A-10	13 May 60	2nd stage attitude control failure.
24 (E)	Explorer S-66	19 Mar 64	3rd stage premature cutoff.
33 (E)	OSO-C	25 Aug 65	premature 3rd stage ignition.
59 (LTTATD) (E)	Intelsat 3A (F1)	18 Sep 68	1st stage shook apart at 107 seconds.
73 (LTTATD) (E)	Pioneer E/TETR C	27 Aug 69	destroyed by RSO at 8 min., hydraulic pressure loss.
*86 (W)	ITOS B	21 Oct 71	2nd stage tumbled; payload failed to orbit, booster 1971-91A.
96 (LTTATD) (W)	ITOS E	16 Jul 73	2nd stage attitude failure.
134 (LTTATD) (E)	OTS A	13 Sep 77	failure of solid booster at 54 sec.
Thor Able Star			
- (E)	Courier 1A	18 Aug 60	1st stage malfunction, destroyed after 1½ minute.
- (E)	Transit 3A/Greb 2	30 Nov 60	2nd stage failed, destroyed by RSO.
- (E)	Composite 1	24 Jan 62	2nd stage misfired (contained 5 payloads).
- (E)	Anna 1A	10 May 62	2nd stage ignition malfunction.
- (W)	Transit 5BN3/SN 40	21 Apr 64	human error by flight controllers.
Thor Agena (W)			
TAA@	Discoverer 0	21 Jan 59	Agena exploded on pad, Thor saved.
TAA	Discoverer 1	28 Feb 59	probably failed, never crossed Navy Spasur fence, 1959 B1.
TAA	Discoverer 3	3 Jun 59	injection angle incorrect.
TAA@	Discoverer 9	4 Feb 60	Agena damaged by launch tower.
TAA	Discoverer 10	19 Feb 60	guidance failure, destroyed 52 sec.
TAA	Discoverer 12	29 Jun 60	insufficient velocity for orbit.
TAB	Discoverer 16	26 Oct 60	2nd stage failure to separate.
TAB	Discoverer 22	30 Mar 61	2nd stage guidance failure.
TAB	Discoverer 24	8 Jun 61	2nd stage ignition malfunction.
TAB	Discoverer 27	21 Jul 61	RSO destroyed after 60 seconds.
TAB	Discoverer 28	4 Aug 61	2nd stage malfunction.
TAB	Discoverer 33	23 Oct 61	2nd stage shutdown early.
TAB	Discoverer 37	13 Jan 62	malfunction followed 2nd stage ignition.
TATAD+	area survey	28 Feb 63	guidance failure, destroyed by RSO.
TATAD+	area survey/pickaback	18 Mar 63	2nd stage malfunction.
TAD+	area survey	26 Apr 63	possible insertion failure.
TAD+	area survey	9 Nov 63	-
TATAD+	area survey	24 Mar 64	-
TAD+	area survey	2 Sep 65	guidance failure, destroyed by RSO.
TATAD+	area survey	4 May 66	-
LTTATAD	Nimbus B/Secor 10	18 May 68	gyro failure, RSO destroyed at 2 min.
LTTATAD+	area survey	17 Feb 71	exploded after 40 seconds.
Thor-FW4 (W)			
-	USAF metsat	7 Jan 66	-

* Launch was partial success in that orbit was achieved by upper stage.
+ It is impossible to determine whether these launches were intended to be area survey or ferret missions.
- Unknown or undisclosed.
(E) Eastern Test Range, (W) Western Test Range.
@ Since the Thor booster was reused this attempt is not considered a success or failure.

What is particularly noteworthy is the ever increasing percentage of successes achieved by the various Thor Agena combinations. The Thor Agena A was launched 15 times suffering 6 failures, yielding a success rate of 60%. The Thor Agena B failed seven times in 44 attempts, achieving an 84% success rate. The Thor Agena D, first launched in 1962, failed in 3 out of 21 attempts for 86% success. The Thrust-Augmented Thor Agena D, launched first in 1963, succeeded in 59 of 63 attempts for a success rate of 94%. The final version, the Long Tank Thrust-Augmented Thor Agena D, failed only twice in 43 attempts, being successful 95% of the time.

The Thor Agena A programme suffered four failures related to the Agena second stage development. The fifth failure was caused by a malfunction in the first stage guidance system and resulted in the destruction of Discoverer 10 after 52 seconds of flight. If Discoverer 1 failed to reach orbit, that failure also would probably have to be attributed to a failure of the Agena stage. An Agena A stage exploded on the pad on 21 January 1959 but the Thor booster was saved.

The launch attempts of the Thor Agena B resulted in seven failures of which six can be attributed to malfunctions in the Agena stage. The seventh failure occurred when the Range Safety officer was forced to destroy Discoverer 27 after one minute of flight. The three failures in the Thor Agena D launches occurred on 26 April 1963, 9 November 1963 and 2 September 1965. The reasons for the first two failures are undisclosed and the latter flight suffered an early guidance failure. It does appear, however, that the April attempt probably failed at the point of insertion, possibly because of insufficient thrust.

The four unsuccessful attempts of the Thrust-Augmented Thor Agena D appear to be the random failures which seem to be inevitable even in the most reliable of the expendable boosters. Unknown causes produced the failures of 24 March 1964 and 4 May 1966. Guidance failure caused the RSO to destroy the vehicle launched on 28 February 1963. The failure of 18 March 1963 was caused by a malfunction in the second stage.

The two failures of the Long Tank Thrust-Augmented Thor Agena D were caused by problems early in their flights. The first launch resulted in the loss of Nimbus B/Secor 10 on 18 May 1968 after 2 minutes. An unidentified payload was lost on 17 February 1971 after forty seconds in the air. All unidentified payloads launched by the various Thor Agena D configurations which failed to orbit are either area survey missions or ferret satellites.

A Survey of Launch Vehicle Failures/contd.

Table 3 Atlas and Titan Boosted Vehicles

Vehicle/Site	Payload	Date (GMT)	Reason for failure
Atlas Agena			
AAA (29D) (E)	Midas 1	26 Feb 60	2nd stage failed to separate.
AAA (W)	Samos 1	11 Oct 60	umbilical disconnect problem caused 2nd stage failure.
*AAB (111D) (E)	Ranger 1(P-32)	23 Aug 61	Agena failed to restart, no Earth escape as intended, 1961 O1.
AAB (W)	Samos 3	9 Sep 61	Atlas exploded on launch pad.
*AAB (117D) (E)	Ranger 2 (P-33)	18 Nov 61	Agena failed to restart, no Earth escape as intended, 1961 AO1.
AAB (W)	area survey	22 Nov 61	apparent 2nd stage failure.
AAB (145D) (E)	Mariner 1(P-37)	22 Jul 62	guidance failure, destroyed by RSO after 5 minutes.
AAB (W)	Midas F/ERS 3,4	17 Dec 62	-
AAB (W)	Midas H/ERS 7,8	12 Jun 63	exploded just after launch.
AAD (W)	closelook	8 Oct 64	destroyed by RSO.
AAD (W)	closelook	12 Jul 65	destroyed by RSO.
AAD (E)	CTA-6	25 Oct 65	Agena exploded after 6 minutes.
AAD (E)	CTA-9	17 May 66	Atlas control system failure.
AAD (E)	BMEWS E	4 Dec 71	1st stage guidance failure, destroyed by RSO.
Atlas			
100D (E)	MA-3	25 Apr 61	control failure at liftoff, destroyed at 30 seconds.
172D (W)	OV1-1	21 Jan 65	injection failure, no separation.
D (W)	OV1-3	27 May 65	booster exploded at 2 minutes.
D (W)	OV1-7	14 Jul 66	injection motor failed, OV1-8 successful as 1966-63A.
F (Satar) (W)	OV1-11	27 Jul 67	injection motor failed, OV1-12 & OV1-86 successful as 1967-72.
F (W)	-	12 Apr 75	malfunction in Atlas booster.
Atlas Burner 2			
- (W)	12 geo sats	16 Aug 68	protective shroud surrounding 2nd stage failed to separate.
Atlas Centaur (E)			
AC-3 (135D)	R&D test	30 Jun 64	premature 2nd stage shutdown.
AC-5 (156D)	Surveyor test	2 Mar 65	exploded on pad.
*AC-8 (184D)	Surveyor test	8 Apr 66	stranded in parking orbit, 1966-30.
AC-21 (5003C)	OAO-B	30 Nov 70	nose fairing failed to separate.
AC-24 (5405C)	Mariner H	8 May 71	failure of gyros in Centaur stage.
AC-33 (5015D)	Intelsat 4 (F-6)	20 Feb 75	booster failure at separation.
AC-43 (5701D)	Intelsat 4 (F-4)	29 Sep 77	booster failure after 55 seconds.
Titan 3A (E)			
-	R&D test	1 Sep 64	premature transstage cutoff.
Titan 3C (E)			
-	IDCSP B1-B8	26 Aug 66	attitude control failure, destroyed at 82 seconds.
-	DSCS 2-H & I	25 Mar 78	2nd stage failure, destroyed by RSO after 8 seconds.
Titan 3B-Agena D (W)+			
-	closelook	26 Apr 67	-
-	closelook	16 Feb 72	apparent upper stage malfunction.
-	closelook	20 May 72	apparent upper stage malfunction.
-	closelook	28 Jun 73	apparent upper stage malfunction.
Titan 3E-Centaur (E)			
TC-1	Viking test/Sphinx	11 Feb 74	Centaur stage failed to ignite.

* Launch was intended to escape Earth's gravity but failed to do so.
\+ Kenden in *Spaceflight* Vol 20, No 7, July 1978, p. 250, indicates a failure on 26 Apr 67. No confirmation could be made of this attempt and it conflicts with Sheldon's tables where 3 launch failures are noted in 1967.
\- Unknown or undisclosed, (E) Eastern Test Range, (W) Western Test Range

It must be noted that there is conflicting information as to the exact configuration of some Thor Agena launch vehicles. For the purpose of this report, what appeared to be the most reliable information was used.

The Atlas Agena and other Atlas launches

The Agena second stage combined with the Atlas booster was introduced in 1960. As with the Thor Agena combination, the Atlas was used with all three Agena versions. In all, up to the end of 1978, 109 Atlas Agena vehicles were launched. There were twelve failures among these attempts for a success rate overall of 90 per cent. As with the Thor booster, much greater success was achieved with the later vehicle combinations.

The Atlas Agena A was launched four times with two failures for a 50% success rate. On 26 February 1960, the first Atlas Agena A failed when the second stage did not separate after a retro-rocket explosion. On 11 October 1960 an umbilical disconnect problem caused a later second stage failure. These failures resulted in the loss of Midas 1 and Samos 1 respectively.

The Atlas Agena B was launched 29 times with five failures for a success rate of 83%. On 9 September 1961, Samos 3 was lost when the launch vehicle exploded on the pad. Another Samos was lost on 22 November 1961 when the second stage of the booster failed. A NASA launch failed on 22 July 1962 when the Mariner 1 (P-37) flight to Mars ended after five minutes following a guidance failure resulting in the RSO destroying the booster. Midas F/ERS 3 & 4 were lost on 17 December 1962 when the Atlas Agena B failed for an undisclosed reason and Midas H/ERS 7 & 8 failed on 12 June 1963 when the vehicle exploded just after launch. Partial failures occurred when Rangers 1 and 2 were left stranded in Earth orbit. These last two missions will be covered in more detail later.

By far the most successful of the Atlas Agena boosters

Table 4 Third Power Launch Vehicles

vehicle	payload	date	reason for failure
ELDO			
Europa 1 (F-7)	–	30 Nov 68	3rd stage early shutdown
Europa 1 (F-8)	–	3 Jul 69	3rd stage failed to ignite.
Europa 1 (F-9)	–	12 Jun 70	3rd stage low thrust, nose shroud failed to separate.
Europa 2 (F-11)	–	5 Nov 71	3rd stage guidance failure.
France			
Diamant B-4	Polaire D2A	5 Dec 71	2nd stage exploded at 147 sec.
Diamant B-5	Pollux D5A/Castor D5B	18 May 73	3rd stage failed to ignite.
Japan			
Lamda 4S-1	–	26 Sep 66	4th stage guidance failure.
Lamda 4S-2	–	20 Dec 66	4th stage failed to ignite.
Lamda 4S-3	–	13 Apr 67	3rd stage failed to ignite.
Lamda 4S-4	–	22 Sep 69	3rd stage struck 4th stage.
Mu 4S-1	–	25 Sep 70	4th stage failed to ignite.
Mu 3C-3	CORSA SS-4	4 Feb 76	
India			
SLV-3-1	Rohini	10 Aug 79	2nd stage guidance failure.
United Kingdom			
Black Arrow (R-2)	Orba X-2	2 Sep 70	2nd stage shut down early.

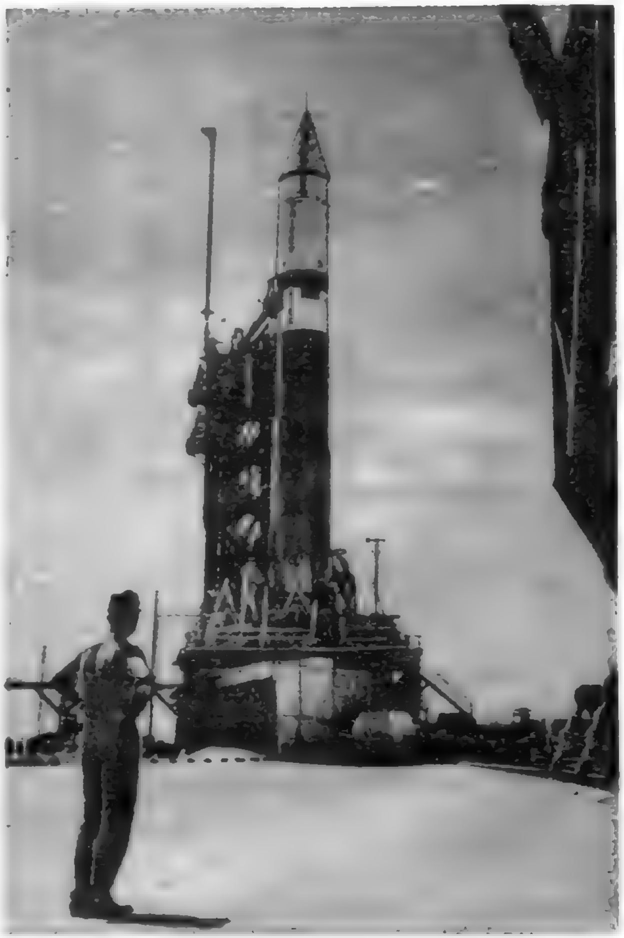
utilized the Agena D second stage. Between 1963 and the end of 1978, 76 of these vehicles were launched and 71 orbited payloads for a success rate of 93%. Ironically, most of the 5 failures in this booster can be attributed to the Atlas first stage. Close-look satellites were lost on 8 October 1964 and 12 July 1965 when the RSO destroyed the booster in flight and BMEWS E early warning satellite was lost on 4 December 1971 when a first stage guidance failure lead to the destruction of the vehicle by the RSO. The other two failures occurred in NASA launches when the target vehicles for GT-6 and GT-9 were lost. GTA-6 failed on 25 October 1965 when the Agena stage exploded after 6 minutes of flight and GTA-9 was lost on 17 May 1966 when the Atlas control system failed.

Malfunctions in Atlas boosted launch vehicles have occurred on other occasions as well (see Table 3). On 25 April 1961, NASA lost MA-3 when Atlas 100D suffered a control failure at lift-off and was destroyed by the RSO at 30 seconds after launch. Atlas 172D failed to orbit OV1-1 when no separation occurred and pod injection failed on 21 January 1965. OV1-3 was lost on 27 May 1965 when the Atlas D booster exploded after 2 minutes.

On 14 July 1966 and 27 July 1967 events occurred which give headaches to those who attempt to define the success and failure of launch vehicles. The first launch resulted in the orbiting of OV1-8 (which became 1966-63C) but failed to orbit OV1-7 when the injection motor failed to lift the spacecraft from the Atlas D booster. The second launch was by an Atlas F (Satar) Vehicle and it orbited OV1-12 and OV1-86 (1967-72A,C) but lost OV1-11 when the injection motor failed. For the purpose of this discussion these launches will be considered successful for statistical purposes, but will be listed among the individually identified failures on Table 3.

On 12 April 1965, an Atlas F failed to launch an unidentified payload when the Atlas vehicle malfunctioned. The only other identified Atlas failure (excluding the Centaur Vehicles considered later) occurred when the Atlas was mated with the burner second stage. On 16 August 1968, the Atlas Burner second stage failed to orbit 12 small geodedic satellites when the protective shroud surrounding the Burner 2 stage failed to separate precluding the second stage from operating.

Between 1958 and the end of 1978, 30 launches were made using the Atlas B, D & F vehicles with four complete failures giving a success rate of 87%.



CENTAUR. Third flight vehicle in the Centaur programme on Launch Complex 36, Cape Canaveral. Launched on 30 June 1964, it suffered a premature second stage shutdown. The first Centaur launching in 1962 failed when fuel tank shielding broke off 54 seconds after lift-off.

NASA

Centaur

The Centaur second stage was first flown with Atlas 104D in a suborbital attempt on 8 May 1962. That flight ended in

EUROPA. Although Britain's Blue Streak first stage worked perfectly each time, ELDO's Europa rockets never did achieve orbital flight. This picture shows an early firing at Woomera in which only the first stage was "live".

Hawker Siddeley Dynamics

failure when the nose fairing failed and the vehicle exploded after 55 seconds.

Following that launch attempt, 48 Atlas Centaur launches succeeded in 88% of the flights attempted, resulting in only six failures. Two R&D flights failed when AC-3 had a premature second stage shutdown on 30 June 1964 and AC-5 exploded on the launch pad on 2 March 1965. Four operational failures occurred later. On 30 November 1970, OAO-B was lost when AC-21 suffered a problem in the nose fairing which caused the spacecraft to fail to separate. Mariner H was lost on 8 May 1971 when the gyros in the Centaur stage malfunctioned and AC-24 failed. AC-33 failed at separation on 20 February 1975 resulting in the loss of Intelsat 4(F-6). On 29 September 1977, Intelsat 4(F-4) was lost when the booster failed after 55 seconds on AC-43.

On seven occasions the Centaur second stage has been mated with the Titan IIIE booster. All of these firings were successful except for the first R&D shot on 11 February 1974 carrying a Viking test spacecraft and a Sphinx satellite. That vehicle failed when the Centaur stage failed to ignite. The Titan 3E-Centaur launches failed in one attempt of seven for an 86% success rate.

Titan as a booster

The Titan has been used in several other variations since the mid-1960's and has achieved a consistently high success rate. During 1964 and 1965, the Titan IIIA was tested four times with the only failure occurring on 1 September 1964 when the transtage cut-off prematurely.

The Titan IIIC was first launched in 1965 and has since been fired 30 times. The two failures have resulted in a success rate of 93%. The first failure ended in the loss of IDCSP B1-B8 on 26 August 1966 when a failure in the attitude control system resulted in the destruction of the booster after 82 seconds. The second loss occurred on 25 March 1978 when a second stage failure caused the vehicle and DSCS 2H and 2I to be destroyed eight minutes after launch.

The Agena D was first mated with the Titan in 1966. The Titan 3B Agena D has since been fired 57 times with only four failures. The booster has been successful 93% of the times. Failures occurred on 26 April 1967, 16 February 1972, 20 May 1972 and 28 June 1973. The cause of the 1967 failure is undisclosed, but the other three failures all apparently were related to malfunctions in the Agena stage.

Planetary Failures

Several partial failures have occurred which are considered successes for the purpose of this article. These five launches were all attempts to escape Earth's gravity. They resulted, however, in Earth orbits only. A Thor Able I launched Pioneer 1 on 11 October 1958 and that Moon probe reached a height of 70,700 miles but had insufficient thrust to reach the vicinity of the Moon. Pioneer 3 was launched by a Juno II on 6 December 1958 and also had too little thrust to reach the Moon. Ranger 1 (P-32) and Ranger 2 (P-33) were launched to the Moon in 1961 by Atlas Agena B's but both became stranded in parking orbit when the Agena stages failed to restart. Atlas Centaur 8 was launched on 8 April 1966 with a Surveyor development payload which was to be fired out of Earth orbit. This launch also failed to take the payload beyond the parking orbit.

Other National Booster Programmes

An interesting comparison can be made between the United States launch vehicle failure rates and those of the vehicle development programmes of other nations, not including the Soviet Union (see Table 4). Statistically, the most successful of these launch vehicle programmes was that of the French Diamant. Starting in 1965, that booster was fired 12 times with 10 successes for an 83% rate. The failures occurred with Diamant B-4 on 5 December 1971 when the second stage exploded at 147 seconds and Diamant B-5 on 18 May 1973 when the third stage failed to ignite. The Diamant was the first successful non Soviet-American booster.

The Japanese entered the launch vehicle field in 1966 with the Lamda 4S booster which was launched five times with four failures for a success rate of 20%. The Mu vehicle has been launched nine times since 1970 with only two failures for 77% success. On 25 September 1970 and 4 February 1976 the Mu booster failed to orbit the intended payloads. The N launch vehicle was first fired in 1975 and, as of the end of 1978, was successful in four straight attempts.

The British Black Arrow was launched twice. The first launch failed on 2 September 1970 when the second stage shut down prematurely. The second launch was successful in 1971 giving the vehicle a success percentage of 50%.

The European Launcher Development Organization (ELDO) made four attempts to orbit payloads with their Europa launch vehicles. One attempt was made each year between 1968 and 1971. On 30 November 1968 the F-7 vehicle failed when the third stage shut down early. The F-8 booster failed on 3 July 1969 when the same stage failed to ignite. The third stage also was involved in the failure of F-9 on 12 June 1970 when the nose shroud failed to separate and the third stage developed insufficient thrust. The final attempt failed on 5 November 1971 when the third stage malfunctioned on the

F-11 vehicle. ELDO thus failed to achieve a successful orbit with the four Europa launches. That R&D effort, however, should bare fruit with the upcoming Ariane programme, just as American and Japanese follow-up programmes achieved much better success rates than did the development programmes in the early years of the space age.

Summary
From the first Vanguard launch of 1957 through the end of 1978, the United States attempted 839 space launches. According to the criteria established for this article 738 of those launches were successful and 101 were failures. Thus, 88% of all launches attempted were successful. With the increased use of the Space Shuttle, it appears likely that the number of expendable booster launches will greatly decrease after 1980 and will probably be nearly phased out in the United States by the mid-1980's. Even if every future launch by an expendable American booster is successful, it appears unlikely that the total percentage of successes will increase above 89%. What seems certain, however, is that it will not be long before the definitive history of the expendable boosters in the United States can be written.

Sources Consulted
The data relating to space failures came from the *Table of Earth Satellite and Space Vehicle Failures*, 1957-1973 prepared by J. A. Pilkington and privately reprinted by him in 1974; the various yearly editions of *Astronautics and Aeronautics*, prepared by NASA and published by the US Government Printing Office; the various yearly editions of *Aeronautics and Space Report of the President*, published also by the US GPO. *TRW Space Log, 1975, 1976 and 1977*, prepared and published by TRW Systems Group (this source must be used with care since it contains some unconfirmed information); *Outer Space-Battlefield of the Future?*, prepared and published by the Stockholm International Peace Research Institute, 1978; *Missiles and Rockets*, by Kenneth W. Gatland, MacMillan, 1975; *World Wide Space Activities*, Report of the Committee on Science and Technology, US House of Representatives, September 1977; *United States and Soviet Progress in Space: Summary Data*, Report of the Committee on Science and Technology, US House of Representatives, April, 1978; and various issues of *Spaceflight* magazine. Appreciation must be given to Dr. Charles S. Sheldon II of the Library of Congress for his generous assistance.

The statistics relating to launch successes came from many of the above sources and in addition, RAE's *Table of Earth Satellites*, Vol. 1, 2 and parts of Vol. 3.

This article takes the record of Launch Vehicles Failures, excluding the USSR and China, to the end of 1979. We hope to continue the account in later issues.

REVIEWS

Murmurs of Earth: the Voyager Interstellar Record
By Carl Sagan and others, Hodder & Stoughton, 1979, 287 p., 16 colour plates, £7.95.

In 1971 and 1972 Pioneer 10 and Pioneer 11 were launched on their missions to the outer planets, both on trajectories which will eventually take them right out of the solar system. Affixed to each spacecraft is an aluminium plaque etched with a drawing describing something of the epoch and locale of our civilisation, portrayed in a language which, it is hoped, will be comprehensible to a scientifically knowledgeable society. There is also a sketch of two human beings, greeting the cosmos.

In 1974 the Lageos satellite, intended among other things to measure continental drift, was launched into an orbit which is expected to keep it up for 8 million years. It too bears a plaque, showing maps of the continents as they were over 200 million years ago, as they are today, and as they are expected to be when Lageos descends.

Carl Sagan was involved with both these messages, the one to distant times and places, the other to the future inhabitants of Earth. When the Voyager missions, the first detailed and close-up study of Jupiter, Saturn, their satellites, and Saturn's rings, were planned, and it was known that these craft too would leave the solar system, the project manager asked him to organise an effort to place messages for a possible extraterrestrial civilisation aboard them too.

At first only a modest extension of the Pioneer plaque was planned, but then Frank D. Drake of the Arecibo Observatory suggested that a long-playing record be sent; as well as sound, pictures could be encoded in the audio spectrum, so the same physical space could be used to send many more pictures than could be got onto a plaque.

This was done: each Voyager has attached to it a record in an aluminium cover, with instructions for playing the record, in scientific language, etched on the cover, and a cartridge and stylus, also illustrated, tucked into the spacecraft nearby.

In this book, Carl Sagan describes the origins of the idea and the aims of the Voyager mission; Frank Drake writes on the foundations of the record, and other ideas for communication with extraterrestrial intelligence; Jon Lomberg, an artist, tells of the selection of the pictures – over a hundred, all reproduced and described in the book; Linda Salzaman Sagan, Carl's wife, also an artist (she drew the human figures for the Pioneer plaque) describes the spoken greetings, in 55 languages, and these are listed, with English translations, speakers' names, and other information about the langauges represented – and those not represented; Ann Druyan, creative director of the record, tells of the 12-minute sequence, "The sounds of Earth" – volcanoes, weather, animals, footsteps, heartbeats, laughter, fire, tools, agricultural and construction sounds, Morse code, transportation (including a Saturn V liftoff), a kiss, infant cries, an hour of EEC patterns reduced to a minute of sound, and a pulsar; and Timothy Ferris, producer of the record, writes about the selection of the 87½ minutes of music – Bach, Mozart, Stravinsky, Beethoven, Louis Armstrong, Chuck Berry, Blind Willie Johnson, and folk, traditional and ethnic music of many lands – 27 items all told.

All the contributors bring out the pressure to produce the record in time, with NASA's intractable schedule always in mind, the great deal of work that had to be done in a short time – securing legal permission for the use of all the pictures, etc. – and the compromises that were necessary – most notably, the separation of pictures and sound, rather than, say, having human voices along with pictures of people, animal sounds with animal pictures, or music accompanying the illustrations of musicians, a violin, and a music score. There was also a problem in that, although the principle of encoding pictures on a disc was in theory simple, the technology to do it just didn't seem to exist – until a small company in Colorado, Colodaro Video Inc., was discovered, which had just developed the necessary machine. They carried out the work free of charge, as a public service and out of enthusiasm for the project. CBS Records did much the same for the music,

securing the releases from copyright, mixing the music as well as all the other sounds, and cutting the wax masters, entirely as a public service.

The book is well-illustrated: the pictures that were sent in colour are in colour here too, and there is also a colour section on the Voyager project itself, as well as many more photographs, maps and diagrams. There are a few annoying misprints, and some inconsistencies (the list at the front says "Greetings in fifty-four languages", but Linda Sagan's contribution says 55 are represented, and the list does indeed number 55), and there should have been more careful checking of the references from other parts of the book to the numbered Voyager pictures, many of which do not match up. The book has been reproduced directly from the American edition, which means we find "color" and "aluminum", and also, in the flight paths diagram on page 225, American-style dates, in which "9/1/77" means the 1st September, not as it would here the 9th January. There is a good index.

In sum, then, a detailed, fascinating, and in some places beautiful record of humanity's most elaborate attempt to devise a message (to quote the title of Carl Sagan's introductory chapter) "For future times and beings".

RAY WARD

America's Journeys into Space, the Astronauts of the United States
by A.J. Cipriano, Wanderer Books (New York), 1979, 212 pp. $6.96

This is a book written by an aficianado of the American manned space for kindred souls. Indeed, the author is a doctor of dental medicine. However, he has done his research well insofar as it covers the earlier years of the American space programme.

The book consists of brief biographies of the astronauts involved in Mercury, Gemini, Apollo, Skylab, and Apollo-Soyuz Test Project, with short mission summaries. It also includes biographical data on astronauts who were killed in aircraft crashes but not those who died otherwise or left the programme for other reasons. Thus, the reader will find no mention of Tony England and John Bull, who, names notwithstanding, were early American astronauts. Neither will be find a summary of Anthony Llewellyn, who was born in the UK, or Brian O'Leary, who was not born in Ireland. The point is that the astronauts included in this book appear to have been selected by some arbitrary and eclectic process.

In attempting to do a book of this type on a programme as ephemeral as the American manned space programme, an author is doomed to be overcome by events before he finishes correcting the proofs. Thus, Fred Haise has left the ranks and is no longer scheduled to fly the Space Shuttle on its third orbital mission.

The book has also another serious shortcoming. The men and women who will be flying the Space Shuttle receive scant coverage, having their pictures displayed only. The majority of them are listed as astronaut candidates, though they have recently become fully-fledged astronauts.

Some of the biographical data of the early astronauts seems to be of questionable value. Does anyone today really need, or care, to know that John Glenn has green eyes? His hair, listed as red, is, alas, a memory only today.

The glossary of space terms in the Appendix is almost embarrassing and wholly unnecessary: "D ring – a ring with one flat side," "Ion – an electrically charged atom or fragment of an atom," and "Aerospace (From aeronautics and space). Of or pertaining to both the Earth's atmosphere and space".

MITCHELL R. SHARPE

CORRESPONDENCE

BAA's Proud Record

Sir, I was surprised by the disparaging comment on the BAA by Mr. E. Coffey at the 34th AGM, i.e. "The people in the BAA have had all the enthusiasm knocked out of them..." (*Spaceflight*, June 1980, p. 266).

May I perhaps make a comment or two?

The BAA was founded in 1890. Its observational record is second to none; it is, I think, recognized as the world's premier amateur astronomical society – note also that its Past Presidents include several Astronomers Royal. It has always had an excellent relationship with the BIS. As I have been a BAA member for 46 years (and a BIS member for about 36), I feel that I may know a little more about it all than Mr. Coffey does!

I am also slightly peeved that the so-called London Group conveys the impression that it is a branch of the BIS. Of course it isn't, and I feel that its members would be best advised to do the decent thing, go off and form a society of their own, and stop wasting everyone's time!

PATRICK MOORE,
Selsey,
Sussex.

Safe-guarding the Society

Sir, With reference to the "society-within-a-society" controversy, this has to be guarded against. The Scottish Branch of the Society, of which I was secretary for nine years, was eventually broken up by just such a mole.

DONALD MALCOLM,
Paisley,
Scotland.

Navigational Beacons for Daedalus

Sir, Reading of Project Daedalus in Bob Parkinson's *High Road to the Moon* and realising that the successful lunar landings were once born in the imagination it does seem that the time is ripe to suggest a start on interstellar flight.

The Daedalus Starship navigation charts will be at least four dimensional and be seen in three dimensional projections set to a Universal Time clock.

Daedalus will need a datum. Like our own UK Ordnance Survey datum at Newlyn it need only be arbitrary and as stable as necessary for the job. The datum is intended to resolve the near light velocities of acceleration and deceleration problems. By spacing the datum twin beacons at ten yearly intervals it is proposed to overcome the translation of the relativistic velocity/time variations between observer points on the datum frame.

To borrow the observer on Einstein's moving tram and an inertial observer in the street, both observers will have two telegraph poles with clocks as points of observation in common. The Daedalus and beacon computers called say Synchron will by transformation analysis convert for each observer the differential coordinates as set against the datum which is common to all.

The original idea for a space datum as sent to Patrick Moore in August 1979 was:

Twin beacons to take up positions at Midnight at X no. Earth diameters apart. The stations to be locked on to 9 no. inter-triangulated constant extra galactic emission sources. To maintain relative position to the extra galactic sources the vehicles

are to be powered on a journey to keep them precisely in the position held by the Earth at Midnight 1.1.2000 A.D.
Responses from Patrick Moore, Sir Bernard Lovell, and Franklyn D. Martin at NASA were ones of interest and encouragement, but all, as did Dr. John Becklake, stressed the need for mathematical calculations.

This article is therefore written in open terms to all those mathematicians in the B.I.S. to take up, along with any other interested members, the Society's traditional challenge of discussion, criticism and help in the development of this idea.

Stages for the construction of the datum are:

1 Two equatorial fixed orbit satellites.
2. Two solar orbit annual pass satellites to line up over the north/south polar axes. These are to study the Theories of Relativity and aberrations for supply to Synchron.
3. The placing of the twin beacons is to be by the Space Shuttle. McDonnell Douglas say they will be active for this task, say, in the late 1990's.

The true direction of the Solar System's trajectory will need to be established or given an assumed mean.

After propelling the beacons at about one third the speed of light it is now necessary to think in terms of the beacons as being the only coordinate system as our Solar System appears to recede.

Twin beacons are to follow at ten yearly intervals to keep up relay contact and establish the space route for coming and going vehicles. The datum will also plot our position in the changing spiral of our Galaxy and eventually relate us to other galaxies.

Computer Synchron is to be self repairing and self renewing and is to contain all instructions to maintain position, measure all deviations, report and retain them as well as being able to return to the datum base fix by the aligning of Fe 57 crystals, the objective always being to hold the position of the Earth as at 1.1.2000 A.D.

CHRISTOPHER VILES,
Surbiton,
Surrey.

Lifetime Membership?

Sir, If BIS cannot give me a lifetime membership, the next best thing would be to credit my account with the enclosed cheque for £500 and remove yearly dues until the money runs out or my death (which will be by explosive decompression when I forget to count airlock doors, somewhere Up There).

Meanwhile, rather than letting the bank watch it, use the money now, as long as it is entered in the books. If you ever suffer financial reverses, I would be more concerned about losing BIS than losing the money.

I would like to thank you for a year of stimulating reading, and I look forward to the time when I can visit England and meet other members of the Society in person.

KEITH LOFSTROM,
Space Research Coordinating Committee,
Sherwood,
Oregon,
USA.

Time Warp?

Sir, My *Spaceflight* for December 1979 (*despatched from UK 15 November*) arrived 14 February, and my *Spaceflight* for January 1980 (*despatched 16 December*) arrived 15 February.

I simply thought you'd like to know the arrival dates here in the USA. Thus, knowing the shipping date, you readily can see how long it takes for delivery.

HAROLD S. BATES,
Hudson,
New York, USA.

Putting on the Style

Sir, I would like to congratulate you on the February 1980 issue of *Spaceflight* with its attractive new type-face and the fascinating blend of articles from the Salyut 6 missions to the Aries sounding rocket. *Spaceflight* is the best over-all source of space information available today.

JOEL POWELL,
Calgary,
Alberta,
Canada.

Jupiter's "New" Moon

Sir, The June 1980 edition of *Spaceflight* had a full description of the discovery of Jupiter's 14th moon known as 1979J1 by G. Edward Danielson and David Jewitt. Readers might be interested to know that David Jewitt has only recently moved to the California Institute of Technology from England where he had been an active member of the Lunar section of the British Astronomical Association.

When you look at the photograph on page 245 of the June issue of *Spaceflight*, you realise just how little Mr. Jewitt had to go on, and he and Dr. Danielson are to be congratulated on their discovery.

GEOFFREY HUGH LINDOP,
Cardurnock,
Kirkbride,
Carlisle.

Naming the "Tenth" Planet

Sir, May one protest against the proposed use of "Odin" as the name of the prospective tenth planet, as suggested by Dr Hammerton, Dr. Rawlin and Mr. Lawton? Surely there *is* a "monopoly on the use of Latin or Greek" myth in naming the objects in the Solar System, with the exception – and then only owing to their excessive number – of the smaller asteroids. And it has been observed throughout the discoveries made from Galileo's day on. The Norse and other mythologies remain available (as in L. Sprague de Camp's usage) for extra-solar planetary systems, in one of which Odin would have the place equivalent to Jupiter in ours. In accordance with the recent habit of giving "deeper" names to the further planets, Arthur Clarke's "Prosperpine" (was it?) or "Dis" would be suitable.

ROBERT CONQUEST,
London.

Bulgarian Cosmonaut

Sir, I would like to thank you for the detailed articles in the February 1980 issue of your very interesting magazine concerning the flight of our first Bulgarian cosmonaut Lt.-Col.-engineer Georgi Ivanov in Soyuz 33.

Georgi Ivanov is well and in spite of our Minister of National Defence General Dobri Djuzov forbidding him to fly, he began to fly again in Russian supersonic jet-fighters (MiG-21). We want Lt.-Col. Georgi Ivanov to live and we are afraid of an aeroplane accident, but the love of Ivanov is the sky. The son of General Djuzov, Captain-engineer Chavdar Djuzov, died a few years ago in a jet-fighter crash. He was also a candidate cosmonaut from Bulgaria.

May I take this opportunity to thank you on behalf of many people from the Bulgarian Air Force who were very pleased and proud to read the articles in *Spaceflight*.

MIROSLAV MARKOV,
Capt., Pilot-engineer,
Sofia,
Bulgaria.

What's in a name?

Sir, You won't ever have to change the initials of the Society's name, just up-date the middle word as space travel evolves. It may not be too imprudent, in the light of the Society's *Project Daedalus Report*—and NASA's Pioneer and Voyager spacecraft to make it the "British Interstellar Society", and at some later date (perhaps sooner than we think!) the "British Intergalactic Society". So it can forever be "B.I.S."

MIKE HARPER,
Blackheath,
London.

Sir, With regard to the Society title, may I suggest that perhaps now is the time to change it to "British Interstellar Society"? I will leave it to a Society member in 2131 to suggest "British Intergalactic Society"!

SALLY LORD,
Cranfield,
Bedford.

Fate of Zond 4?

Sir, The letters by Nicholas L. Johnson and Saunders B. Kramer on the Soviet Zond 4 satellite reminded me of some references to it in the UFO literature.

On the evening of 3 March 1968 there was a big display of multicoloured objects seen over the eastern USA. Several witnesses described the objects as "cigar-shaped", "windows giving off strange lights", etc. Naturally these sightings at once became spectacular UFO reports.

Hartmann (1969) writes: "These objects were soon identified by NORAD as pieces of the Zond 4 probe or its rocket booster and identification was finally confirmed on 1 July 1968 (see *New York Times*, 2 July 1968)".

Both Walter Sullivan and Donald H. Menzel describe the "Spectacular UFO's of 3 March 1968" as the fiery re-entry of either the Zond 4 satellite or its booster. Apparently the satellite had only been launched the previous day.

I mention this case *not* as evidence either for or against UFO's but merely to give a fresh bit of information on what may have been the final demise of Zond 4 or its rocket.

Incidentally this case is one of the best examples I know of to illustrate the point that reports of UFO sightings should *never* be taken at face value.

C. D. ALLAN,
Alsager,
Stoke-on-Trent

The 3 March sightings in fact were debris of the re-entering rocket stage. Ed.

REFERENCES

1. E. U. Condon, *"Scientific Study of Unidentified Flying Objects"*, 1969 (Section VI, Chapter 2, by William K. Hartmann).
2. *"UFO's, a Scientific Debate"*, Cornell University 1972. (Chapter 6 by Donald H. Menzel and Chapter 13 by Walter Sullivan).

Refinements of Soyuz T?

Sir, In the February 1980 issue of Spaceflight, Robert Christy concluded his article "Orbit of Soviet Spacecraft at 51, 6° Inclination" by suggesting that the two Cosmos satellites 1001 and 1074 were test flights of a Soyuz spacecraft with new systems. His conclusion has now, in my opinion, been verified with the launch of Soyuz T on 16 December last year which was officially described as an improved Soyuz carrying new radio communication, orientation and movement control systems and a computing complex. Because nearly all new manned Soviet spacecraft are tested unmanned under the Cosmos programme, this new type has gone the same way of testing. The reason why the Soviets called the launch of 16 December Soyuz T and not Cosmos is that it docked with Salyut 6.

In the same article Robert Christy suggested that this new type of Soyuz may have room for a crew of three; the same is also suggested in *Flight International* of 12 January 1980, which also suggests that because of this, the landing parachutes are repositioned and the batteries for electrical power are replaced by fuel cells.

If the latter is true, the problem of an emergency return after a fault during the docking sequence which occurred with the flight of Soyuz 15, 23 and 25 has disappeared. Because of a shortage of electrical power their crews could not stay in orbit to find the fault, correct or repair it and try again.

To make the Soyuz-Salyut programme more efficient, the above is necessary; only time will tell if the Soviets have made these changes.

PETER STUIT,
Groningen,
The Netherlands

Return to Apollo

Sir, I have just read the article "Return to Apollo" in your January, 1980 issue.

I find it one of the finest articles on the Apollo Program I've ever seen, except for the sentence (p. 19): "No pad fire would have brought the date of the first lunar landing forward to mid-1968 at the latest."

In Michael Collins' *Carrying the Fire* (your ref 1), it is specifically said (pp. 276–7): "I don't think the fire delayed the first lunar landing one day, because it took until mid-1969 to get all the problems solved in areas completely unrelated to the fire."

Thank you.

JOHN FADUM,
Deerfield Beach,
Florida, USA.

SATELLITE DIGEST — 141 *Continued from page 350*

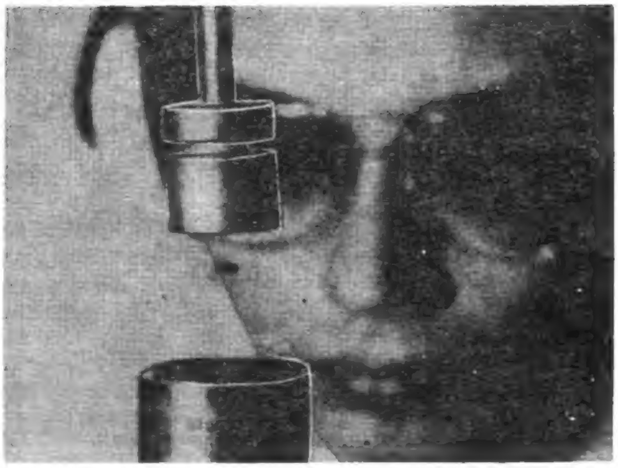
Supplementary notes:

(1) Navigation satellite as part of US Global Positioning System.
(2) Unmanned ferry carrying supplies to the crew of Salyut 6 (Popov and Ryumin). Progress 9 docked about Apr 29.34. It undocked May 20.79 and was de-orbited over the Pacific Ocean. Orbital data are at April 27.3, 28.4 and 29.2.

(3) Radar carrying ocean survey satellite similar to Cosmos 954, and powered by a nuclear reactor. Minor orbit maintaining manoeuvres are carried out using a micro thruster.
(4) Long-life manoeuvrable reconnaissance satellite.
(5) Orbital data are at 1980 May 7.6 and 8.2.
(6) Cosmos 1179 may be related to the navigation satellite system; its orbit plane is separated from that of Cosmos 1181 by 45°.
(7) Cosmos 1181 may be a navigation satellite.
(8) Orbital data are at 1980 May 23.3 and May 23.4.
(9) Manned spacecraft carrying an international crew to Salyut 6. The Commander was Valery Kubasov and the Flight Engineer Bertalan Farkash of Hungary. Soyuz 36 docked at May 27.83. The crew returned to Earth in Soyuz 35, landing Jun 3.630 after a flight of 7.866 days. Popov and Ryumin later undocked Soyuz 36 from the rear docking port and re-docked with the forward one to enable the later docking of Soyuz T 2 Progress 10. Orbital data are at 1980 May 26.8, 27.1 and 29.2.
(10) Orbital data are at 1980 May 28.6, 29.1 and 29.5.
(11) US meteorological satellite intended for a 99° inclination, 870 km orbit. A booster fault caused the incorrect orbit and as a result the satellite has been shut down.
(12) Possibly an electronic ferret.
(13) Manned test flight of a modified Soyuz craft, already tested unmanned as Cosmos 1001, 1074 and Soyuz T 1. The crew Commander was Yuri Malyshev, and his Flight Engineer Vladimir Aksyonov. The craft docked with Salyut 6 about Jun 6.67. Orbital data are at Jun 5.7, 5.8 and 7.0.
(14) Cosmos 1185 is an Earth resources satellite. Orbital data are at Jun 6.3 and 7.4.
(15) Orbital data are at Jun 12.6 and 13.4.
(16) USSR communications satellite intended for the Statsionar 4 location at 14° west longitude.
(17) Possibly an early warning satellite. Orbital data are at 1980 Jun 14.4 and Jul 4.4.
(18) Combined meteorological and Earth resources satellite.
(19) US reconnaissance satellite and smaller pick-a-back with its own motor. The Big Bird is manoeuvrable.
(20) USSR domestic communications satellite. Orbital data are at 1980 Jun 21.8 and 26.9.
(21) Orbital data are at 1980 Jun 27.3, 27.4 and Jul 6.3.
(22) Unmanned ferry carrying supplies to Popov and Ryumin aboard Salyut 6. Progress 10 docked about Jul 1.25. Orbital data are at 1980 Jun 29.4, 30.7 and Jul 1.4.
(23) Possibly an early warning satellite. Orbital data are at 1980 Jul 2.1 and 8.1.
(24) Multiple launch of eight satellites, possibly for military communications although the launch announcement mentioned remote sensing as part of their mission. There may then be more than one type of payload. One orbit is shown for each satellite.

Amendments:

1978-36A, Cosmos 1001 description, weight and dimensions should be amended to match those of Soyuz T 2.
1979-8A, Cosmos 1074 description, weight and dimensions should be amended to match those of Soyuz T 2.
1979-33A, Cosmos 1094 decayed on 1979 Nov 7, lifetime 203 days.
1979-36A, Cosmos 1096 decayed 1979 Nov 24, lifetime 213 days.
1979-63A, Cosmos 1112 decayed 1980 Jan 21, lifetime 199 days.
1979-103A, Soyuz T 1 description, weight and dimensions should be amended to match those of Soyuz T 2.
1980-27A, Soyuz 35 was recovered with the Soyuz 36 crew 1980 Jun 3.630, lifetime 55.062 days.



DEFYING GRAVITY. Marshall Space Flight Center engineer Bruce Ross uses sound waves to suspend a water droplet in mid-air. Scientists at Marshall are experimenting with a concept called acoustic levitation for suspending molten materials during processing in the low gravity environment of space. A levitator could be used to hold free-floating material in place in a space furnace without the use of a contaminating container.

NASA

FILM CLUB

Society Film Shows have always proved very popular but the number of films immediately available to us is limited. This is why they have been repeated many times; the small supply of films has also both reduced the number of film shows which can be held each year and restricted the choice of material presented.

The Programme Committee has now undertaken a survey of films available from commercial sources and believes that the number of film shows could be increased substantially if the problem of meeting the hire charges payable on such films can be overcome. At present it would average about £1 per member attending.

To provide an opportunity for members who might wish to attend these special film shows, yet without putting the cost on the general body of members unable by distance or otherwise to attend, the Committee has made the following proposals:

a. Normal film shows planned by the Society and open to all members free of charge should continue, on the basis of two or three each year.
b. These shows should be presented, in future, on two consecutive days, thus giving individual members an added choice of dates as well as allowing more members to see each programme.
c. Additional film shows should be scheduled, if supported by members, to screen films available from non-Society sources and for which hire charges are payable. A self-supporting Film Club should be set up, open to every member of the Society and their guests, to provide enough subscriptions to cover the hire costs involved. A membership of at least 40 will be needed to make the scheme viable.
d. Initially, six two-hour evening programmes could be arranged for the 1980-81 session. The fee for these six meetings would be £5.00, but other members wishing to attend a programme in which they have a particular interest, will be able to do so, if seating is available, for £1.00.
e. Members who would like to join the scheme are asked to apply to the Executive Secretary for a Registration Form, enclosing S.A.E.